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Introduction

One summer morning in 1993, I surprised my friend Gene Terray by meeting him for breakfast at the Woods Hole Bakery. I had just returned to Woods Hole from a two-week cruise on board a University of Miami research vessel. I dominated the discussion, as we ate our muffins, relating stories of my experiences from the recent cruise. I told him about the successes and the failures, the competence of the Woods Hole Oceanographic Institute (WHOI) scientists, and the mistakes of some of the “first-cruise” researchers. I’m sure I made Gene a bit late for work that morning, but he didn’t seem to mind.

I had first met Gene in 1991 when we spent two and one-half weeks as roommates on a research platform in the North Sea. Working with Gene was a pleasure because he is bright, has a good sense of humor and has great common sense, an all too rare combination. In the Spring of 1993, I again worked with Gene on an experiment* sponsored by The Johns Hopkins University Applied Physics Laboratory (JHU/APL), where I work as a research oceanographer.

*Throughout this book I speak of oceanographic experiments. Many will argue with my choice of words, suggesting the replacement of the term ‘experiments’ with ‘observations’. While it is strictly true that we go to sea to make observations, everything about these observations is carefully planned in order to maximize the information we will receive about the phenomenon of interest. While it is unarguably true that our ability to replicate oceanographic experiments is limited by the variability of nature, we do possess a great deal of control in our choice of time, location and instrumentation. Webster’s defines experiment as “An act or operation designed to discover some unknown truth, principle, or effect, or to establish it when discovered.” Thus I think my use of the term experiment throughout this book is both proper and fitting.

Gene politely listened to my stories and complaints about those researchers that had never been to sea before. Whenever I go to sea, there are always amusing and sometimes outrageous stories to tell when I return. Such sea stories are a tradition amongst oceanographers and serve the purpose of teaching what to do and what not to do at sea. When I had vented my last story, Gene made a comment that goes to the heart of why I have written this book. Gene said that when he had first started working at WHOI, he had asked a colleague what made WHOI special. His colleague’s reply was simply, “WHOI knows how to do oceanographic experiments.” Gene at first thought this answer was ridiculous. He was trained as a physicist and experienced in performing complex laboratory experiments. What could be so hard about performing oceanographic experiments? After all, you just go to sea, deploy and recover your instruments, and then return to analyze your data. Gene said that it was years before he understood what his colleague had meant. In Gene’s experiences over the years, it became apparent to him that few individuals, and even fewer organizations, actually knew how to run a good oceanographic field program. I was proud when Gene said that from what he had seen, JHU/APL knew how, placing my organization in the same class as WHOI. I agreed with him that running a successful field program was much more difficult than it looked and that a tremendous amount of experience was needed to pull off such experiments.

For months after our conversation, I found myself thinking back to the point that Gene had made. Why is it so hard to do at-sea work? Why is the expertise concentrated in only a few organizations? How can this expertise be transferred to others to help insure their success?
This book is an attempt to convey some of the wisdom and experience that I have gained over the years in how to conduct at-sea experiments. Much of what I have written here can be viewed as basic common sense, but it is a common sense derived from years of at-sea work. It is surprising how many researchers ignore the basics when they go to sea. This book is meant for those who are going to sea for the first time, but I would hope that even those with considerable at-sea experience would benefit from at least some of the ideas expressed herein.

Throughout this book I have tried to reduce the lessons that I have learned into single, simple phrases. I’ll take this opportunity to point out that only one of these rules is absolute (Safety first.) All of the others are best thought of as guidelines. On any given field experiment I usually break a few of my rules myself. The point is that when I do break a rule, I have carefully considered the consequences. Those times that I don’t follow the rules quite often end in trouble, so the point is that I think carefully before doing.

There is a certain arrogance that accompanies experience and it certainly takes some ego to write a book about such a broad topic. Despite this I want to make it clear that I do not have all of the answers. If you understand and follow the rules I have laid out here, I can guarantee you will have a higher probability of a successful cruise. There are no guarantees, though, of ultimate success and you will certainly learn your own lessons as your career in oceanography progresses. And that really is the final, most important point — you should learn something new every time that you go to sea. Every experience, whether good or bad, should be treated as a learning experience.

A friend related the story of a successful scientist who was asked the key to performing good experiments. Without hesitation he replied, “Making right decisions.” “But how do you know how to make the right decisions,” his questioner continued. The answer was but a single word, “Experience”. A little frustrated, the questioner then asked, “And how do you gain experience?” “By making wrong decisions,” was the reply. I hope that the scientist’s last answer was a bit incomplete and that you can learn from the mistakes and experiences of others.

Each chapter in this book addresses a separate topic in the conduct of oceanographic measurements. Throughout I have tried to relate true stories of my experiences at sea. Each of these experiences inevitably led to my learning a new lesson. You’ll notice that I do not include the names of people or organizations that are the brunt of these stories. There are three reasons for this omission:

1. I am afraid that I would get the pants sued off of me by those who feel slandered by my comments, and I don’t look particularly good in just my boxers. (Although, I’ll remind anyone that is tempted to sue, that truth is an absolute defense against libel.)

2. The omission of names will provide hours of enjoyment for my friends and colleagues as they try to guess to whom I am referring in particular passages.

3. The point of the stories is not to denigrate the reputations of individuals or institutions. I instead want to illustrate how ignorance can lead to mistakes. It is my hope that we can all learn from these mistakes.

Everyone makes mistakes, and to illustrate this point throughout the book I have made a single exception to my own rule of not mentioning the names of individuals who screw up: in those cases where I was the one at fault, I’ll admit it. The danger of this policy is that once you have read about some of the stupid things that I have done during my career, you may question the validity of the whole book. Please don’t. I think I have learned from my mistakes and I hope you will too.
Chapter 1. The At-Sea Experience

Going to sea to make oceanographic measurements is one of the last two romantic jobs in the world. (I think the other is game show host, but that’s the topic of my next book.) The sea has always held humans in its sway. Ever since that fateful Tuesday morning eons ago when our ancestors crawled from the muck of some pond, we have yearned to return. There is something primordially relaxing about just being on the water. The slow sway of the boat deck under your feet, the warm summer breeze that caresses your face, the warmth of the setting sun that paints the sky with streaks of red. When you are working at sea, always remember that people pay large sums of money to go on sea cruises. You may find solace in these thoughts when you can’t stand on the heaving deck of your 50 m research vessel being buffeted by 6 m high waves, when the gale force winds are causing spray to crash over the sides of the ship soaking you to the bone, and when, in all of this, you have to wrestle a 500 kg buoy from the sea, praying that you don’t get crushed or thrown overboard. Working at sea is great.

Even when you are comfortably inside your shipboard laboratory, difficulties abound. Because of the rolling seas, everything must be tied down. During a stretch of calm weather numerous small objects such as tools, supplies, or laptop computers will be brought out of storage and left to sit on table tops. When the wind and waves grow again, as they invariably do, loud crashes will be heard to emanate from the lab as a result of these items falling to the floor. And when things really get rough, you’ll find that you’ll have to wedge yourself into bed in order to sleep; you’ll have to keep both hands free in order to catch yourself as you walk down a corridor; and you’ll even have to hold onto your plate at meals in order to steady it so that the food does not slide off onto the table.

To further compound these difficulties, your goal in going to sea is not to perform manual labor under rough conditions, although that may be one of your jobs. Your goal is to make scientific measurements at sea. Scientific measurements, of any kind, are difficult to make well. Scientific measurements at sea are doubly difficult. You may be operating under conditions that will stress your mind and body. And throughout this you’ll be expected to operate complex and sensitive electronic equipment and data acquisition systems. As the waves and environment wear on your body, the accelerations, shocks and salt air will corrode your equipment. Equipment will break when you are far from shore and the nearest Radio Shack. Equipment failures are a fact of life at sea and you will have to learn to deal with them. When I go to sea I don’t wonder if something will break, instead, it is a question of how often and how many things will break.

If you haven’t planned carefully you may even run out of supplies. I was on a cruise once where we ran out of paper. It’s difficult to do science without paper! If you think that is outrageous, how about the story related to me by a colleague regarding an experiment on a U. S. research platform where they actually ran out of drinking water! (If this ever happens to you, pray you are on a European research platform. Then at least you can switch from water to beer.)

And despite all of these difficulties – all of the stresses of life at sea, the isolation, and the hardships – you’ll be expected to bring home the data. No excuses. The success or failure of your cruise will be judged in the short term by whether you succeeded in making high-quality measurements, and in the longer run by the science that you and others are able to decipher from these data. The importance of your success cannot be over-stressed. Your career may well depend on it. No data, no analysis, no papers, no tenure. It really is that simple. If you
think this unjust; if you think people should be given credit for a good attempt, think again. Think about the large sums of money that some sponsor has invested in each cruise. Going to sea is not a game and it is not for the unprepared, unwary, or undedicated.

On the positive side, there is no feeling that I know like successfully completing a long and arduous cruise. There is no satisfaction that I know like overcoming the elements, the equipment failures, personnel conflicts, and all the rest that go with sea tests, to bring home the data. At the end of a hard, successful cruise I have a feeling of elation and a feeling of accomplishment that only other sea-going oceanographers can fully understand. In sharp contrast, at the end of an unsuccessful experiment I feel like death. I guess it’s just the Vince Lombardi in me.

I realize that this may seem overly dramatic to many. But these are the ways I think about working at sea. In later chapters I will try to explain why I feel this way and why I think you should too. My overall reasoning, though, is quite easy to understand. I think that preparation, knowledge, experience and attitude are critical to success. Of these elements, attitude is the one attribute that forces you to do your best. While experience takes time to acquire, a positive attitude and the resolve to succeed will lead you to prepare and to gain the knowledge necessary to succeed.

Of course, the at-sea experience is not one of isolation. I know of no sea-going oceanographer that does his work alone. There are invariably other oceanographers, engineers, technicians and crew aboard a research vessel. In fact there are so many others involved in a typical oceanographic experiment that you should stick with theory if you want to work alone. Your work may well depend on the relationships you forge with others on your cruise. For example, I work hard to be on good terms with the deck crew because I know that my success depends upon their skill and diligence in handling my equipment during deployment and recovery operations. I try to stay on the good side of the technicians and engineers as I may need their help to repair wayward equipment. And naturally a good relationship with fellow scientists is important to insure that you get sufficient data opportunities on the cruise as well as cooperation in the post-test analysis phase. This book cannot teach you how to get along with people, but I will stress that your relationships with your shipmates may determine your success or failure.

Finally, going to sea is not all work. It should be both educational and fun. Inevitably there are long stretches of little to do. In an extreme case, one colleague actually became so bored on a cruise that he talked the Bos’n into letting him chip paint! Personally I prefer less strenuous activities, but I can understand my colleagues desire to do something, even anything. In a more personally constructive vein, I suggest that you work on forming good relationships at sea. Then, the in-between times can be fruitfully spent in conversations with your new friends that can teach you many new things about the sea, about ships, and about your profession. Alternatively, you can spend all your time watching movies. It is your choice.

I have been in this business for over 25 years and I still believe that I can learn something from the most junior seaman that I meet, as well as the top scientist. What I know of deck handling, comes from the teachings of countless deck crew that have befriended me over the years. My knowledge of navigation comes from numerous late night hours on the bridge conversing with the third mate. I have been taught knots by cooks and ocean acoustics by ship engineers. The fact that people know a lot should not be amazing. Instead we should be amazed at our own tendency to categorize and dismiss the knowledge of others. I treat each cruise as an ongoing seminar and suggest that you do the same. It will not only make the time fly, but it will improve your knowledge of, and standing within, your chosen profession.
I close this briefest of introductions to life at sea with some words from the opening to *Moby Dick*. Melville’s words express a passion for the sea far better than my own feeble demonstrations ever will:

Whenever I find myself growing grim about the mouth; whenever it is a damp, drizzly November in my soul; whenever I find myself involuntarily pausing before coffin warehouses, and bringing up the rear of every funeral I meet; and especially whenever my hypos get such an upper hand of me, that it requires a strong moral principle to prevent me from deliberately stepping into the street; and methodically knocking people’s hats off – then I account it high time to get to sea as soon as I can. This is my substitute for pistol and ball. With a philosophical flourish Cato throws himself upon his sword; I quietly take to the ship. There is nothing surprising in this. If they but knew it, almost all men in their degree, some time or other, cherish very nearly the same feelings toward the ocean with me.

Actually I lied. There is one more point I want to make before I close this chapter. Throughout this book I make suggestions touching on all aspects of life on board ship. As you read on, you’ll probably come to believe that I have an authoritative opinion on every subject under the sun, no matter how small or mundane. And finally you may come to the conclusion that I am either one arrogant SOB, or the only person in the world to go to sea with, or some combination of both. I think it is important to address this right up front because I hope that such mis-impressions won’t cloud the information I am trying to convey.

As to the first possible conclusion, it is true, as I said in the introduction, that there is a certain arrogance that accompanies experience. My defense is that I do not believe that I have all the answers, and you shouldn’t either. I’ll tell you a bunch of things in this book, but you should concentrate on how the experiences I relate might be helpful to you in your work. Most of the knowledge that I try to relate here I have gained from others. So in the truest of senses, I am but the messenger.

As to the second possible conclusion, I do think I’m reasonably good at what I do, but I have been to sea with a lot of people that are better oceanographers and better field scientists than I am. This I readily admit. It could be that I’m writing this book instead of them, simply because they are out at sea working and I am not. In any case, there are wonderfully talented people throughout our field, and one of the messages of this book is to seek them out and learn from them.
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Chapter 2. Planning

In this chapter, I’ll try to describe those elements that occur before the cruise, at least those that are not instrumentation specific. These are described under the general title of planning, but these pre-test activities are wide ranging in scope. Despite the breadth of planning activities, this entire chapter can be summed up by a single rule:

*Plan everything, including the unexpected.*

This rule may be short, but it is anything but simple. It requires years of experience to know what to plan and how to anticipate the unexpected. I’ll describe those items which I have come to think of as important, but in the end, you’ll have to learn for yourself. Still, I hope you will consider my comments carefully, because planning is the heart of conducting a good experiment.

Planning needs to begin with the scientific ideas and goals that you want to accomplish on your cruise. These should be expressed within a science plan for the experiment. An explicit elaboration of these goals is important in nearly all experiments.

You may enter into collaborations with other scientists, or you may be on your own, but you will inevitably be working within a team. Your role in the team, what you will contribute and what you expect from others, should be explicitly agreed to before the experiment. A discussion and agreement, prior to the experiment, on the roles everyone will play will go a long way towards avoiding misunderstandings during and after the experiment.

Coordination of action during the test is critical. A written test plan can provide the common ground to insure that everyone understands what is going on, and works together towards the common goal of a successful experiment. The test plan should cover a variety of topics including organization, test conduct, communications, and navigation.

If your test involves multiple platforms, or relies on some form of data exchange with shore facilities, then communications planning should be a high priority. Communications always seems to be the first thing to break down under field conditions. While this may be surprising at first, there are good psychological as well as physical reasons for this that will be discussed.

I have never been on a cruise where we didn’t need to know where we were and what time it was. With modern satellite-based systems this should be easy. Still, mistakes are constantly made and it has been my experience that the navigation and timing on research cruises are generally inadequate. In this day and age navigation and timing are not hard to do, but they do deserve careful planning and attention. I know that providing for navigation and timing sounds incredibly mundane, but it can turn out to be of critical importance.

Finally, I’ll discuss the truly trivial matters of what to pack and how to get it onto the ship. This should not require a Ph. D., but a few tricks that I have developed over the years should make this a more enjoyable experience. (Actually this is a relative statement. Packing and loading a ship is always a crummy job, but someone’s got to do it.)
Scientific Planning and Collaborations

Scientific planning and goals

In planning an experiment the very first thing is to settle upon a set of experimental goals. Without a clearly written set of goals, experiments grow and transform in obscure ways, which can lead to a failure to accomplish anything. A clear vision of the reasons for an experimental program is needed, and this vision needs to be shared among all of the participants.

Sometimes, due to politics or funding constraints, the participants and instruments will be settled upon before the goals of the experiment are set. This is unfortunate, because invariably, one could choose a better set of collaborators to perform the desired measurements than those selected by a sponsor. When this happens to you, as it likely will at some point during your career, my advice is to make the best of it. Make the effort to determine exactly what expertise, instrumentation and research interests each party can bring to the experiment. Meshing these into a single unified whole may be difficult, but it is well worth the effort. If you fail to try to accommodate investigators selected by your sponsor, then the slighted investigators will complain to the sponsor, who will then make their unhappiness evident to you. Unless the stipulated investigators are total bozos, try to get along.

The more normal and productive course is to select investigators and capabilities based on the stated scientific objectives and goals. While it is important to select people that can work together, the usual criteria are based almost entirely on expertise and capability.

[Keeping this in mind will help you when you are deciding on future research areas. When adding capability, it may be better to complement existing capabilities within other research groups rather than duplicating those capabilities. There are all kinds of interesting areas in my own field that I avoid, because I know that other groups around the country provide a sufficient capability in those areas to meet potential sponsor’s needs. I think it better to move into areas where I see a niche that is not filled. The great thing about oceanography is that there are lots of such niches to be filled and lots of areas where our ignorance exceeds our wisdom. It may be a funny reason to recommend a science, but I think it is our ignorance within oceanography that makes it such an interesting field of study.]

Collaborations, contracts and agreements

Typically, the investigators you will be working with are respected, intelligent scientists with solid research programs. While some investigators prefer to work alone, most will welcome collaborations with others. By eliminating duplication of efforts, successful collaborations allow limited research dollars to be stretched, benefiting everyone involved. In contrast, unsuccessful collaborative efforts can degenerate into the worst kind of bedlam, engendering bad feelings between those involved, hindering the advance of science. I have been involved in both good and bad collaborations over the years and there are a few rules that I have learned.

First, collaborations among newly introduced scientists are often tentative and prone to failure. When I was younger I assumed that everyone shared my enthusiasm for collaboration and my views on sharing data. I quickly found out that some scientists were wary of my openness. They didn’t know me and thus had no reason to trust me. In a competitive world such as science, where money depends on both your ideas and your success in selling them,
there is a natural tendency to be wary of strangers. I have learned that it is best to take collaborations slowly, stressing the advantages of the collaboration to all parties concerned.

The second key is to form an explicit contract describing what each party will do for, and receive from, the other parties in the collaboration. This agreement should be reached as early in the collaboration as possible. I am not suggesting that everyone hire lawyers, but everyone should clearly understand what is involved in the collaboration. A colleague of mine once collaborated with a scientist at another institution. Going into the collaboration they agreed that both of their names would appear on any papers resulting from their joint work. The first paper, which my colleague wrote, went smoothly. A disagreement then arose over the authorship of the second paper. My colleague took the typical view that the person who wrote the paper should be first author. His collaborator, who was a good scientist but not much of a writer, felt that he should be the first author on the second paper, no matter who wrote it. He reasoned that he had been the second author on the first paper, so he should be the first author on the second paper. While most would view this as an unreasonable request, the collaborator didn’t feel it was and so a problem developed in the collaboration. My colleague would have been better off if he had known and discussed his collaborator’s expectations before he entered into the collaboration.

A good collaboration should be like a partnership, with all involved contributing something to, as well as taking something from the partnership. On one occasion I suggested to a colleague the use of one of my current meters as part of his measurement platform, a towed catamaran system with lots of other instruments. At first he was nervous that I was trying to get some free credit for latching on to his already successful program. After convincing him that I was not interested in taking credit for his accomplishments, he agreed to the scientific utility of adding my current meter. The next hurdle came several weeks later after a planning discussion, when I brought up the topic of data sharing. My colleague had somehow gotten the impression that I was going to provide my current meter without any strings attached. I corrected him, suggesting that we fully share all of the data from his instruments and my current meter, with the proviso that I would not use his data for anything other than the work with the current data. Furthermore I suggested that all of our initial work and publication be joint, at least on those aspects of the problem again involving my instrument. I thought this was a reasonable and fair proposition. Again he was wary, but after thinking about my proposal for a few days he accepted. From these rather tentative beginnings our work together turned out to be an extremely pleasant collaboration. The key was that it was based on trust, mutual respect, and a clear understanding of what was expected of each participant.

In contrast, I entered into another collaboration with a scientist to share certain data for an intercomparison of systems. It later turned out that the scientist that I reached an agreement with was but one of three scientists who were working with these data, and the other two were not thrilled to have me as a working partner. (I think they were concerned about spreading the credit for their work to thinly.) It eventually worked out because they wanted my data as much as I wanted theirs, but the tensions ran high for quite some time. I had to endure a number of angry phone calls and long discussions about my role in the collaboration. While some good work has come out of this effort, in retrospect, I doubt if I would have entered into this collaboration knowing the difficulties involved. Entering into a collaboration is just like buying real estate – it is best to know exactly what you are getting into before you sign on the dotted line.
Science Plan

Any experiment that involves more than one investigator needs a clear and detailed science plan. Such a document is normally required by sponsors, but is useful even when it is not required. A typical plan would consist of an introduction outlining the scientific problems to be investigated. A background section would detail pertinent knowledge in the field and point out the needs for additional data that this program will supply. The scientific objectives would then be described in clear and concise terms. The next section usually describes the general methodology of the program, listing investigators, instruments, platforms and program organization.

This document is not the same as a test plan, which contains detailed information regarding the conduct of the experiment. It instead provides an overview of the program goals and approaches that should be useful to both your sponsors and fellow investigators. The process of planning an experiment can be likened to the planning of a symphony orchestra’s performance. In this analogy, the science plan is like the evening’s musical program that is decided upon by the artistic director of the company. It is the document that provides the overall direction and sets the common goal for the performance. In contrast, the test plan is like the musical score. It specifies in great detail how the performance is to be carried out, who is to play which notes, and exactly at what time. This analogy can be carried further. The director is the chief scientist, the orchestra members are the other scientists, the custodial and support staffs are the ship’s crew, and the paying audience are the sponsors! (I can hear my colleagues now, quipping that my role in this orchestra would be to play the Bassoon, spelling it either with an ‘ass’ or a ‘uff’.) In fact, the only major difference that I can see between an oceanographic experiment and a symphony orchestra is that the orchestra’s test plan has usually been written by a guy who’s been dead for several hundred years.

The science plan should act to document the scientific intent of your program providing a focus for subsequent test planning. Getting all of the co-investigators to agree to a science plan is an important step in getting everyone to work together to meet the goals of the experiment. Experiments conducted without a science plan are likely to degenerate into a set of separate investigations, with everyone making their own measurements in support of their own research. While such disjoint experiments can yield good results, they are never as productive as a carefully coordinated program. The ideal is to get everyone thinking and working collectively and towards a common goal.

Assigned Responsibilities

It has been my experience over the years that technicians should not be sent to sea to run scientific equipment by themselves. Technicians may be trained to operate equipment, but only a scientist can do science; and science is the ultimate goal of measurements at sea. This observation may seem a bit out of place, here in the chapter on planning, but it is but one element of a larger point I want to make about assigned responsibility.

I was once on a short cruise investigating near-surface internal waves. The scientist responsible for the CTD measurements on this cruise decided to attend a professional meeting and sent a well-trained technician in his place. In the end I was impressed with the technician’s knowledge and technique with the system. His sole problem was that he didn’t understand the scientific objectives of the experiment. The technician had been given enough cable to do CTD profiles to a depth of 1000 m, and so that is what he intended to do. Never mind that the mixed layer depth was less than 50 m. Never mind that the internal waves of interest were essentially confined to the upper 100 m or so. He had 1000 m of cable and he
was going to use it. Given the fixed speed of the profiling this was a ridiculous waste of time, but the technician didn’t seem to mind. On this experiment, the time necessary for a single deep cast could have been better spent performing multiple casts in the important near-surface zone. Any scientist would have recognized this tradeoff and modified the sampling strategy accordingly. The technician stubbornly stuck to his strategy despite my protests to the contrary.

(The one good that came from this debacle was that I got to shrink a large number of styrofoam cups to hand out as souvenirs to friends and acquaintances. In case you are ever involved in a cruise where deep casts are to be made, be sure to take along a mesh laundry bag and a bunch of 8 oz styrofoam cups. When the cups are sent down to depth in the laundry bag that is attached to the instrument, the pressure crushes them surprisingly evenly, shrinking them to the size of a thimble! You can even write cute messages on them before they are sent down, and your writing comes back as small as the shrunken cup. I use a full size cup, along with a shrunken cup, in talks that I give to elementary school kids to get them to think about what it is like on the bottom of the ocean. As a hint, it is best to send the cups down stacked. They are a bit more difficult to get apart this way, but they don’t distort as much.)

The larger point here is that each instrument system, whether it be a simple CTD or a complex manned submersible bristling with sensors, should be the responsibility of a single scientist. This is not to say that one scientist cannot handle more than one instrument. And it is not to say that some instruments aren’t so complex that they require several scientists for their care and feeding. The point is that in the end, a single person has to take responsibility for each instrument and measurement that is taken. By identifying a single scientist as responsible for an instrument, you are assuring yourself that either that scientist will make certain the instrument is used with the proper care to make the desired measurements, or that scientist’s reputation will suffer. Without such an assignment of responsibility, the details that are the difference between good and bad measurements are too often lost between the cracks. Henry W. Menard, a famous geological oceanographer, said [Menard, 1969], “Experience shows that we rarely get first-class records unless the scientist who will eventually study them is on board the collecting ship or at least personally involved in the expedition.”

**Graduate Students At Sea**

If my opposition to technician’s working alone at sea isn’t bad enough, I’m going to compound the effrontery and suggest that the same prohibition should stand for the majority of graduate students. In general, I don’t think graduate students should be sent to sea without the presence of their major advisor, or at least someone on their committee or within their department. As this book is directed in large part to graduate students, I have probably offended you at this point. Before passing judgment though, please allow me to explain.

I just recently returned from a deployment on the Research Platform **Flip**. There were two pairs of graduate students on **Flip** that had been left there by their major professors. One pair worked hard to keep their equipment going, they showed significant interest in learning about the other research projects, and were always happy to lend a hand when some work needed to be done. Their professor had trained them well.

The problem was with the other two students, who could have been the first two student’s evil twins. Unfortunately, problems with their equipment left them with little to do. They responded in the worst possible way by doing nothing during the cruise. They showed no interest in anyone else’s work. They rarely offered to help anyone even though they were constantly in the way. To make matters worse, one of them, who had never been to sea
before, repeatedly violated the rules of life on *Flip*. He managed to flood the scientist’s sleeping area not once, but twice, by forgetting to turn off a toilet valve. Despite an explicit proscription, he repeatedly took showers during meal times, making it difficult for the rest of us to wash our hands on the way to the mess. When you’re on a platform as small as *Flip* for any length of time, these kinds of transgressions take on major proportions. By the time we got off *Flip*, all of us were either mad at, or disgusted with, these two.

I later found out that the novice student was sent to sea by his professor to satisfy his department’s cruise requirement. Prior to this experience, I was all for cruise requirements in general, but as far as I can see this particular student gained nothing from his experience, while hindering the work of the rest of us. I don’t think this is what the department had in mind when they passed this requirement.

*Flip* is a 110 m long cross between a spar buoy and ship. *Flip* consists of a 90 m long tube containing a large floodable sea water tank with 20 meters of a ship’s bow welded to one end. *Flip* is deployed by towing it out to sea in the horizontal position — it has no propulsion system of its own. Once *Flip* has arrived at the desired location, the sea water tank is flooded and *Flip* begins to sink. When sufficient water has entered the tank, the aft end of *Flip* actually sinks completely, leaving the forward compartments sticking straight up out of the water.

This unique design makes *Flip* an incredibly stable platform from which to work. As the crest of a wave passes a normal ship, the ship heaves upwards in response to the force exerted by the extra volume of water it displaces. The ship is accelerated by this force, proportional to the volume of water displaced, acting on the mass of the ship. When *Flip* is in the horizontal position, its wetted area is roughly its length times its beam or width. When it is in its vertical position though, its wetted area is reduced to \( \pi \) times the square of the radius of its body. Its mass is actually larger in this vertical position, because of the water it has taken on as ballast, and its wetted area is much smaller, making it extremely stable.

This is not my only example of a wasted graduate cruise. When I was in graduate school, a professor in my department sent a student on a cruise to the equatorial Pacific by herself, despite the fact that the student was working on a computational degree. Upon the student’s return, she was required to give a seminar on her experience. I remember her slide show vividly. She began with pictures of the boat. (Her terminology, not mine.) Then there were some pictures of her clowning around with the new friends she made on board. Then there was a picture of her sunbathing on the steel beach above the wheelhouse. Each picture was accompanied by a small story. Finally, she showed a picture of a Rosette sampler dangling from a winch. She clicked by this last picture quickly though, commenting that occasionally they would stop to lower this instrument over the side. When someone asked her about the instrument she admitted that she had no idea what the thing was. As far as I could see, her trip was an all-expenses-paid cruise and she had not cluttered her mind with any of the research work that was going on around her.

Now I know that there are countless counter examples to the last two stories. Many students are mature enough to go on a major cruise without guidance. But many more are not, and I don’t think valuable cruise time or space should be devoted to the unprepared or unmotivated. This is not a diatribe against grad students. I was once one myself. Instead it is a plea that students be properly supervised on cruises to allow them to get the most out of the experience.

**Test Plan**

Arguably, the single most important document to the success of an experiment is the check from the sponsor for the full amount of the cost of the experiment. Given that the
check is in the mail, as it always it seems to be, the next most important document is the test plan. As I said earlier, without a science plan the test may degenerate into a series of independent tests, one per investigator. In contrast, a test executed without a test plan often degenerates into a dangerous babble of disagreements, arguments, and name calling. A test without a test plan is not a pretty sight.

There are a wide variety of levels of detail found within a test plan. A good plan will include all of the information for a participant to know what, where and when things are supposed to happen during the test. It should provide a guide for individual investigators of their responsibilities during the test. It should provide sufficient information to insure the coordination of all of the participants in the test, especially across platforms, and from land to sea. In most cases it is a supplement to the communications that are a necessity in any test, providing a reference point about which all of the participants can communicate.

I have been spoiled during my years at APL because of the complete test plans that our test group requires that we produce. A typical APL test plan contains an incredible amount of detail. They typically begin with a brief statement of the scientific objectives of the experiment. The second section will contain an overview of operations, beginning with the general and becoming more specific. This overview will list and describe the platforms (buoys, ships, aircraft, or satellites) involved, along with the major instrumentation. It will also describe the general location and timing of the experiment. Following sections, one per platform, then go into more detail about the instrumentation and duties of the scientists on each platform. Finally a number of sections at the end of the plan detail the navigation requirements, any peculiar safety issues, contingency plans in case of bad weather, instrument failures, etc., and an overall communications plan. For an example of the level of detail specified, the communications chapter will provide call signs for all participants, primary and backup frequency allocations, pertinent phone numbers of land-based participants, and details of communications schedules which each platform is expected to follow.

Such a test plan will specify how a test is to be conducted while acknowledging the flexibility that may be required in the field. A typical plan may specify a number of run ‘modules’, specifying specific tracks and instrument deployment schemes to perform a particular measurement. A prototype schedule of such modules may be given, but the flexibility of final module scheduling is left to the ship’s chief scientist. A good test plan allows the experiment to proceed in an orderly fashion while providing the scientists the freedom to make changes if necessary.

Putting together a test plan of this detail is a lot of work. I have been out on experiments that do not have this sort of detail in their test plans. Some have worked well and others have not. It seems to me that a high degree of planning before the test removes considerable risk in actually implementing the test. With a detailed and well-thought-out test plan, individuals can follow the plan without much effort. Without such a plan the success of the experiment relies on individual initiative and numerous decisions made in the field by the participants. While each individual may make good decisions for their own work, there still may be gaps left in the program that could have been avoided through better coordination.

As an example, I was involved in a minor capacity in a multi-national experiment to study radar backscatter from the ocean surface. The planning for this experiment was undertaken by a committee of the senior investigators, but the test plan they produced lacked detail in some areas. After reading over the plan, I asked the principal investigator on the U. S. side whether anyone was bringing a rain gauge to the experiment. He said that he was certain that our foreign colleagues were providing this capability, even though it was not spelled out in the plan. Well, sure enough, when we got out to sea, there was no rain gauge. In the end, we had to rely on hourly notes from the watch that recorded whether it was raining
or not. Meanwhile, two low-cost, easy-to-use rain gauges were sitting 4000 km away, packed in boxes, back in my lab.

I hope I have convinced you of the importance of the test plan. To a certain extent though, this is obvious. The real problem lies in figuring out the right things to do in the test plan. While each cruise and experiment will be different, some of these topics are discussed in general terms in the following sections.

Coordination

Chain of command

The chain of command within the experiment as a whole, and on each platform participating in the experiment, needs to be understood by all participants. While democracy may be a good organizing principle for a country, it would be a disaster on an experiment. Inevitable disagreements occur and decisions need to be made quickly. Democracies would never do for work at-sea. Instead most at-sea expeditions are run as a benevolent dictatorship. (Although some of my colleagues would argue with my use of the word ‘benevolent’ in this context!) The chief scientist is in charge and his word is the law. Despite this power, a good chief scientist will gather everyone’s opinions and weigh the good of the experiment before coming to decisions. Hence my preference for, and use of, the term ‘benevolent’.

Actually, that is not quite the case on an APL expedition. The responsibilities for the cruise are split amongst several people, but this division of responsibility is explicit. As for all cruises, the captain of the vessel is in charge of all issues of safety and navigation of the vessel. The chief scientist is in charge of all scientific matters. And an APL deck chief is in charge of all deck operations. The chief scientist may request a buoy deployment, but the captain or the deck chief can veto the deployment on safety grounds. The system works because the individual’s responsibilities are well delineated and separate. As a working scientist on board a vessel, it is your responsibility to respect this chain of command, and to address your requests, complaints or suggestions to the chief scientist. Don’t directly ask the captain or the deck chief to do things. By respecting the chain of command you’ll keep confusion down to a minimum and will keep the chief scientist informed.

I have been on cruises where scientists bypass the chain of command and the results can be a mess. I have seen scientists that have been banned from the bridge for making requests directly to the crew, countermanding standing orders of the chief scientist and captain! The worst case I ever ran across was on a large experiment that I was running, involving several aircraft, a helicopter and three ships. In the initial planning stages, the scientists on one of the aircraft, a four-engine Navy P3, had requested some flight time at altitudes of 300 feet in order to test out a new infrared remote sensor. Since this system was not directly germane to
the sponsor’s program, and because the helicopter was scheduled to operate from 200 to 600 foot altitudes, their request was denied. The test plan was quite explicit in the restriction that the helicopter was to stay below 900 feet and the P3 was to stay above 1200 feet.

On the first day of testing, the experiment had been underway for about an hour, when I heard the P3, communicating directly with the helicopter pilot, request that the helicopter climb to an altitude of 1500 feet. The helicopter pilot, not wanting to play chicken with a four-engine fixed-wing aircraft readily agreed. I was livid, and the tracking range safety officer was also rather upset. While the helicopter-mounted cameras got some good footage of the P3 flying underneath them, just above the surface, the entire episode was a violation of our safety rules and a waste of valuable research time.

The P3 pilot, who had been briefed on the restrictions, was ordered to report to the operations center after he landed. The pilot, concerned that he had done something wrong, mentioned his orders to the scientists on board. The scientists told him he needn’t bother going to the operations center, as the scientists had been the ones to direct him to fly the lower course. So, the pilot never showed up. The next morning, when the P3 had taxied out to the end of the runway to take off, the range safety officer refused to give his permission for a takeoff. Instead, the crew was forced to taxi back to the control tower, and the pilot had to deplane and report to the control center. There he received the chewing out that he had avoided the previous day. I made certain that the scientists responsible also heard about it, as did the sponsors. Such unilateral breaches of an agreed upon test plan should not be tolerated. These scientists violated safety rules and based decisions on an unwarranted belief in the utility of their data in comparison with data from other platforms.

Not all cases are this outrageous but the lesson should be clear. A strict hierarchy needs to be set up to execute an experiment and this hierarchy should be respected by all of the participants.

Ship resource allocation

During the earliest stages of planning, participating investigators should relay their requirements and desires for on board space and other shipboard resources to the chief scientist. Space on most research vessels is at a premium, so the fight for space can be brutal. Your documentation of space requirements should include the number of people participating in the cruise broken down by sex; the size, weight and deployment needs of any in-water instrumentation; the size and type (wet or dry lab) of laboratory space needed; special needs such as refrigerator space or explosives storage; and any additional storage needs. [As an aside, laboratory space on most modern day cruises is measured in linear bench space, using the non-SI unit, IBM-PC (or PC for short). Thus I have been known to tell someone that I need three PC of space on a particular cruise. For those of you not familiar with this measure of length, a PC is just enough space to locate an IBM PC, monitor and keyboard with tie downs and a chair for a scientist to work at the system.]
The chief scientist has the responsibility of getting information on the ship for the other investigators (you don’t want ten groups all calling the marine department asking for layout drawings of the ship). He then matches the stated space requirements with what is actually available on the ship, and using a shoehorn and cattle prod, develops a preliminary space allocation plan. Sharing this plan with the investigators prior to the experiment and allowing them to comment on the preliminary plan before making it final can save a lot of problems during the onload.

**Coordination of multiple groups**

In a typical experiment there will be multiple research groups, with differing interests, on each platform. (I use the term platform here, instead of ship, because I have worked from ships, aircraft, towers, or piers. In this context a platform is anything that holds instruments.) This means that a primary responsibility of the platform scientist is to coordinate the research activities of the various groups. This requires a detailed understanding of each group’s research interests and how these interests fit into the context of the overall experiment. This type of coordination is best done well before the cruise, so that the each group has time to consider, and eventually agree to, the chief scientist’s view of their role in the experiment. Reaching an agreement prior to the cruise is key because it will be the chief scientist that runs the operations on the platform. Don’t delude yourself into thinking that disagreements regarding operations, which occur before the experiment, will get settled to your satisfaction in the field. It usually doesn’t work out that way.

At the same time, the platform scientist has the duty to weigh the oftimes competing interests of the groups on board, insuring that each receives their fair share of the data collection opportunities. A perfect example of this occurred on an APL cruise that I went on with Gene Terray. Prior to this cruise a deal was struck with Gene to provide an opportunity for his graduate student to field a new buoy system that he had been developing. APL had agreed to these deployments as partial compensation for Gene’s contributions to the APL experiment. While this new buoy was not of direct interest to the sponsors of this experiment, it was still the responsibility of the chief scientist on the cruise to see that sufficient opportunities were available for the testing of the buoy. Because the balancing of
competing interests at sea often takes on the air of a high wire act, it is best to reach a consensus on the approach to be taken prior to sailing.

**Coordination of multiple platforms**

As difficult as coordinating the activities of a number of different groups on a research vessel is, coordinating activities between multiple platforms is even worse. The problems are inevitably exaggerated by the difficulties of communications. If there is a dispute on board a ship, all of the parties can sit down together and argue for their interests. Communications between platforms are usually limited to radio, a fact that makes open-ended discussions difficult. For this reason, if no other, the chief scientist on each platform must be responsible for communications with the other platforms in the experiment. While all of the platform chiefs will confer on the conduct of the overall experiment, there is still a need for an overall head, or test scientist, to resolve disputes that might occur.

The keys to coordination of multiple platforms are planning and communications. Noting that communications would be almost unnecessary in a perfectly planned experiment, it should be clear that detailed planning of the coordination of platforms should be carried out prior to the experiment. Communications, which are inevitably needed when the pre-test planning proves to be less than perfect, are discussed in more detail in a following section.

**Coordination of preparation and onload**

Some final thoughts on the pre-test coordination of preparation and onload are important. I spend considerable time in this book discussing individual preparation for at-sea work. It is sometimes equally important in large experiments to coordinate the preparations between multiple groups. This is especially true when data are to be shared by these groups. When planning your test, be sure to allow time, money, and support for the coordination of various group’s systems. This can mean testing joint data acquisition systems, fabrication of brackets to hold another group’s instrument on your platform, or just planning on how data will be shared after the experiment.

Coordination and planning of the onload are also important. The chief scientist on the platform should take the lead in keeping all of the participants informed with regard to the onload schedule. In return, individual investigators need to let the chief scientist know about any special requirements that they may have for onload, such as crane support, support for extra heavy loads, welding services to attach buoy cradles to the deck, or any other support which will require the arrangement of special services. The onload schedule should be planned to avoid common problems. Will dock services, such as a forklift, be available? Does the onload occur over a weekend when needed personnel may be off duty? Are sufficient crew scheduled to aid with the installation of equipment? Asking lots of these kinds of questions, along with careful planning, are the keys. When nearly all has been said and done, you should always ask one more question, namely, “Are there any questions that I didn’t ask, but should have?” You’ll know you’re ready when the answer to the last question is no.

**Communications**

Communications is a very important part of any experiment. Unfortunately it is usually the first thing to fail and these failures often have more to do with people than hardware. For this reason it is of critical importance to include some detailed planning for communications in your pre-test planning.
Communications planning should begin by identifying the needs particular to each experiment. For example, all experiments will require communications between personnel on the ship, many experiments will require communications with researchers or support personnel on land, and a few large experiments will require communications between research vessels in order to coordinate their activities. In this section, I’ll discuss some of the communications technologies available for platform-to-platform or platform-to-land communications and discuss some of the limitations that you should expect in current systems. I’ll then discuss communications planning before tackling the more difficult subjects of those aspects of group psychology that affect all forms of communications at sea.

Marisat, cellular phone and fax, telemetry, ...

Communications technology is rapidly evolving. At the time of this writing there are a number of forms of ship communications, but the range of available choices should explode in the next few years as new commercial satellite systems become available. For example, just on the horizon is the Iridium system with numerous low power satellites in low Earth orbit designed to provide universal, inexpensive communications. I hope that such systems, and the competition they engender, will revolutionize communications for oceanographers. Until then we are somewhat limited in our available choices.

At the present time, communications to vessels more than a few hundred kilometers from shore is restricted to either Marisat satellite communications or older and less reliable HF systems. Marisat is an international consortium that provides voice, fax and data communications through a satellite network. The system uses relatively inexpensive earth terminals that are common on most research vessels, but can be rented for those vessels that don’t have a permanent installation. Users of the system pay a per-minute and per-call fee that can be rather substantial for long conversations. Marisat is fairly reliable but not perfect. You should expect some difficulties in establishing connections and will almost certainly experience some lost connections at times. These are worst on temporary installations where the antennas are typically smaller, and in large sea states where ship motions can affect the link. While we regularly use Marisat for fax transmission, we have had mixed success with data transmissions. At this time I would not suggesting relying on Marisat data transmissions as your sole option for relaying data.

Despite its problems, Marisat is still preferable to HF radio systems, which are dependent on the vagaries of ionospheric propagation. These may be useful for the most cost-sensitive experiments, but the unreliability and low bandwidth of the link usually makes regular communications difficult. HF propagation links depend on ionospheric conditions, which vary with time of day, season and phase of the 11-year sunspot cycle.

On the other hand, HF radio can be an interesting diversion on long cruises. Members of my group at APL often take an HF amateur radio rig on board for communications with other amateur operators. Sometimes, they can arrange communications with families back home through a cooperating amateur who will use a device called a phone patch which routes the transmissions into the phone system. This is a bit of a kludge, but it can save considerable money in reduced Marisat charges. As a licensed amateur radio operator I will caution though that operators are required to be licensed and that these communication links are legally restricted to non-business uses.

Closer to shore, the communications channel of choice is the cellular telephone. With a decent antenna mounted high on the ship reliable cellular communications can be maintained out to 100 km. In the Gulf of Mexico, cellular sites maintained on oil production platforms extend cellular ranges to 240 km. Fax and data modems are readily available for use with
cellular systems. Cellular systems are so popular that they are being used by numerous institutions for telemetry and control of remote buoys in the coastal environment.

One problem with cellular phones that you should be aware of is that standard modem communications over a cellular phone range from poor to mediocre. On a recent experiment we used a standard high-speed modem connected to a cellular phone to check our email and exchange small data files with colleagues back home. While the modem would tell us that it had linked at 9600 baud, the actual baud rate was closer to 1200 baud, and that is when it worked at all. The modem industry has responded to these problems by creating new, more robust data exchange protocols. I have not had a chance to try out these new protocols, but I think that cellular modems have a long way to go before they are as easy to use as their wired cousins.

Finally, a few words about data telemetry. Having even a limited real time data link to remote instruments is a big plus. Telemetry systems on surface buoys are often one- or two-way radio links, while many subsurface buoys make use of acoustic modems. In either case, care should be taken to understand the characteristics of the telemetry link, including useable range, dependence on environmental factors such as sea state, and transmission error correction schemes and resultant error rates. Radio telemetry systems that work well over land, will often have reduced performance over water due to multipath interference caused by the proximity of the antennas to the sea surface. When using a new system for the first time, be sure to test it over water beforehand, and to include contingency plans in case the system fails or works only at reduced ranges.

For even more remote operation, Service ARGOS is a satellite-based system for locating and acquiring data from buoys at sea. ARGOS transmitters, officially called PTTs, are at the time of this writing down to as little as $550 per unit. You also pay a daily fee to Service ARGOS for location or data information. Data can be transmitted from your buoy in small, 32-byte packets, so data rates are extremely slow. Still, for longer scale drifter studies ARGOS is hard to beat. In addition to data transmission, the ARGOS system can provide location information for buoys, although the precision is not particularly high (typically 1.5 km). The navigational fixes can be useful for tracking a drifting buoy or finding a buoy that has gotten away from you. Given the cost of a lost buoy, the inclusion of an ARGOS PTT is cheap insurance.

**Communication schedules**

After having decided on the physical system(s) used for communications, you must plan for how those channels will be used. I strongly suggest that communication schedules be developed and maintained throughout an experiment. A communications schedule is nothing more than an agreement to establish contact with other platforms or land-based investigators at particular times. Such scheduling will in all likelihood be flexible, but once a scheduled is agreed to, it should be kept.

On experiments with two ships, we regularly schedule a major communication to discuss the day’s events prior to breakfast each morning. By having a fixed schedule, those scientists interested in contributing to the discussion can join the chief scientist in the conversation. Early scheduling of the daily planning discussion also has the advantage that any major changes to the schedule can be communicated to the other scientists on board at breakfast, before everyone scatters to work on their equipment.

While the communication systems on a modern R/V (Research Vessel) should be monitored all of the time, it is usually inconvenient to track down someone on the cruise
when an outside call occurs. Scheduled communications thus are more efficient for those
items that can wait until the appointed time. There will always be emergencies requiring
immediate communications, but schedules act to reduce the chaos.

Group psychology

Anyone that has attended a college sporting event can attest to the ‘us versus them’
mentality that is generated by such competitions. In the best sporting traditions, team
conflict raises the level of competition without invoking the worst in people. In other cases,
competition acts to reduce people to their basest self, sometimes with dire consequences. If
you think I exaggerate the possibility, just try attending a Washington Redskins game in a
Dallas Cowboys jersey.

I bring this up, because group conflicts inherently arise in the high-pressure world of
working at sea. People seem to have a natural tendency to form groups and the rigors of at-
sea work seem to enhance this tendency. Some of these groupings, such as scientists versus
crew, are a natural extension of cultural or economic groupings that occur in society. But
there are other groups whose formation are unique to the at-sea experience, such as watch
versus watch, ship versus ship, or ship versus land. And just as in the sporting world, these
groupings can be both good and bad.

A healthy competition amongst watches to make the best measurements, can make a
cruise more enjoyable. A competition between those same watches where the goal of each
watch is to minimize their own workload can be destructive. On one cruise I was on, such a
competition began, with each watch working hard to arrange to have the rosette sampler
ready to come on deck just as they were going off duty. The downward spiral of this childish
game led to unnecessary delays in sampling, as well as to hard feelings on the part of the
watches that “lost” the competition.

I have seen similar problems arise between ships and between ship and shore. There are
several reasons for this. Typical communication channels are very narrow, making it hard to
fully discuss an idea or plan. People often transmit instructions, directions or requests without
providing sufficient justification or rationale. This void can lead to doubt in the recipient’s
mind – doubt about the utility of the request, doubt about whether the requesting party
understands the difficulties involved in meeting the request, doubt whether the competing
interests have been properly weighed, and sometimes even doubt about the sanity of the
requestor. These doubts may be compounded in others on board the ship. Because only one
person can be on the radio at a time, the dynamics of the off-ship groups are typically not
fully communicated to the others on ship. This is all quite general and obtuse, so let me
provide a specific example of what can happen.

This story comes from what I like to call my ‘Cruise from Hell’, which actually took
place north of Hawaii several years ago. I had signed on to help out a colleague who needed a
senior scientist to participate in the cruise, providing some quality control and on-site
interpretation of the data. The cruise took place on a modified 150 ft mud boat, which was
our first mistake. (Mud boat refers to a class of ships that were designed with large holds for
transporting mud produced by oil-drilling platforms back to shore.) It turns out that on this
experiment we were looking for big waves and unfortunately for us we found them. I began
the cruise by spending the first three days in my bunk praying for an early death. By the time
I got my sea legs, morale was already starting to fade. We were having problems with key
instruments, the ship’s crew was rather unhelpful, our test engineer injured his back and had
to spend several days in his bunk, and the cook was the worst I have ever seen. To top all this
off, the scientists back on land kept requesting status reports and data that we just couldn’t provide.

In our communications with our colleagues on land we tried to explain the difficulties that we were facing, including trying to correct instrument problems caused by poor installation, software bugs and unexpected equipment failures. They would commiserate with our problems, but then call back several hours later asking for another status report. From my own experience back on shore, I knew that sitting around waiting for status reports from a ship at sea is a very frustrating business. Still, they were driving us crazy with their incessant requests. I finally told them that we would no longer answer the phone if they called. Instead, we would call them back when we got our systems reasonably on line. After a few choice invectives the next day when they called, they got the message and stopped bothering us.

After the initial crises had passed, morale continued to sink because of the poor working conditions and the constant pressure from land to acquire data. I fought back by adding more and more humor to my daily cruise summaries, which we were faxing back to land. With each passing day I would add increasingly outrageous paragraphs about the sighting of sea monsters, the problems we were having with the radiation from passing UFOs affecting our instruments, and other such sundry items. On board the ship, my reports became one of the highlights of each day, with a copy eagerly passed around amongst the scientists and technicians before it was sent off. It had become a struggle of us against them and everyone appreciated that I was fighting back.

The nadir of the cruise came a few days before the end of the test, after a particularly nasty stretch of time when we had lost the data from a large group of drifting GPS buoys that finally gave up the ghost. On that day I wrote an especially long and incredibly bizarre report and faxed it back to land. My friend and colleague, who was running the test from the land site, happened to be hosting a visit from the sponsor and a group of interested scientists on that day. My fax came in, and he decided to read it out loud to his visitors. He was embarrassed to find out that in my frustration I had written a long and comical report that contained absolutely no useful scientific information whatsoever.

After the experiment, I rightfully caught a little flack about this incident. It was unprofessional and I knew better. Still, the temptation to succumb to the dark side of an ‘us versus them’ mentality can be quite strong. The solution is simple but not always easy. The people on each end of the conversation need to attempt to communicate better. One suggestion to improve communications is to actually listen to the other party. (What a radical idea!) Each person should also have a common understanding of the goals of the experiment, the plan that is to be followed, and the difficulties of working at sea. Few things are worse than having an inexperienced person at the other end of the conversation when you are at sea. By trying to put yourself into the shoes of the other person, and by showing a lot of patience, problems of mis-communication can be minimized, if not eliminated.

**Communications etiquette**

In a typical scientific conversation there is a lot of give and take. Scientific discussions are often complex, involving detailed technical arguments put forward to persuade others of our views. This usually works well when we talk to each other in person, but often breaks down when the medium is radio. There are some simple solutions, though, that can help you minimize communications problems at sea.

1. **Try to listen to the other person.** I know I am repeating what I just said above, but it can’t be stressed enough.
2. **Gather your thoughts before speaking.** If you are uncertain of a point, tell the person that you’ll contact them after thinking about the problem. Few things are more annoying then listening to a rambling discussion over the radio. Also be aware that the person on the other end of the radio is likely to be as busy as you, so don’t waste each other’s time.

3. **Be extra polite and courteous.** There are a lot of forces that act to make life at sea difficult. Don’t let those spill over into communications with those not on the ship.

4. **Remember that virtually no ship communications are private.** Usually, there are others listening to both ends of the conversation so don’t say anything that you don’t want everyone to know. This specifically means that you should be wary of discussing personnel problems or other private matters over an open communications link. On one cruise the officer on watch overheard a fisherman call his wife to tell her that the fishing was particularly good and that he would stay out another night. This conversation was immediately followed by a call to the fisherman’s girlfriend telling her that he would be right over. My guess is that there were several hundred people that heard this conversation, and there is no telling if one of these people might have been a friend of the man’s wife.

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**Chain of command**

Although this was discussed previously, I feel compelled to reiterate here that respecting the chain of command is critical for successful communications at sea. The platform scientist should be the focal point for all communications and he should in turn pass on these communications to the other members of the scientific party. Real problems arise when only the chief scientist knows what is going on, but these problems are easily corrected. The chief scientist just needs to maintain a constant dialog with the others on board.

If you are the chief scientist it’s a good idea to use printed notices on a central ship bulletin board (or bulkhead) for the promulgation (great word isn’t it?) of cruise plans and information. There are two reasons for this. First, you won’t always be available to the scientific party when they have a question about the schedule, but the bulletin board will be. Second, given the typical watch schedule, it is usually hard to get everyone together at one time. Thus printed instructions and plans are a handy communications tool.

On experiments that do not involve watches, I suggest you schedule daily experimenter’s meetings. For planning-intensive experiments with complex and variable daily schedules it is best to have this meeting prior to each day’s work. For more laid back experiments, you might want to consider meetings at the end of the day designed to review daily progress. These experimenter’s meetings are a good forum for monitoring the progress of the experiment and getting everyone working together. They need not, and should not, be any longer than is necessary to conduct the business at hand. A typical daily experimenter’s meeting, excluding the first few days of an experiment that are always hectic, may last only 10 minutes. Still, it is a great way to keep everyone up-to-date on the progress of the experiment.
Navigation and Timing

Well we know where we’re goin’
But we don’t know where we’ve been
And we know what we’re knowin’
But we can’t say what we’ve seen
And we’re not little children
And we know what we want
And the future is certain
Give us time to work it out

We’re on the road to nowhere
Come on inside
Takin’ that ride to nowhere
We’ll take that ride...

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These are the opening words to what I have come to think of as the oceanographer’s theme song, The Road To Nowhere by the Talking Heads. As best I can figure, David Byrne, the author of these words, must have been an oceanographer in some past life. To my mind, his words capture that uncertain, lost feeling that you can have at sea facing the unknown, yet struggling to understand. I particularly like the key line “We're on the road to nowhere” because it all looks the same at sea. Lewis Carroll eloquently made a similar point in his epic poem, “The Hunting of the Snark”:

The Bellman himself they all praised to the skies---
Such a carriage, such ease and such grace!
Such solemnity, too! One could see he was wise,
The moment one looked in his face!

He had bought a large map representing the sea,
Without the least vestige of land:
And the crew were much pleased when they found it to be
A map they could all understand.

"What’s the good of Mercator’s North Poles and Equators,
Tropics, Zones, and Meridian Lines?"
So the Bellman would cry: and the crew would reply
"They are merely conventional signs!

"Other maps are such shapes, with their islands and capes!
But we’ve got our brave Captain to thank:
(So the crew would protest) "that he’s bought us the best--
A perfect and absolute blank!"

As Lewis Carroll might attest were he alive today, joint navigation and timing are of critical importance in most voyages and particularly so on oceanographic experiments. Here I am referring to those data that tell you where and when particular measurements were made. If you are out on a ship by yourself, then maybe you need only know where data are acquired to the nearest kilometer and the time of day to the nearest hour. If, on the other hand, your data will be merged with data from other instruments, which may be on other platforms, the need for accurate joint timing and navigation becomes more acute. I use the word joint here
to indicate that often the requirement is not to have high absolute accuracy in timing and navigation, but instead to have high relative accuracies between platforms. I’ll say more on this subject later.

Navigation used to be complicated with lots of choices. Now you only need to remember two systems: GPS and DGPS. GPS stands for Global Positioning System, a rather amazing technology that utilizes a constellation of satellites broadcasting to small receivers on the Earth. For less than $400 one of these receivers will tell you where you are on the Earth to within 60 m rms error. This is cool stuff.

For those cases where 60 m accuracy is not sufficient, Differential GPS (DGPS) comes to the rescue. It turns out that the GPS system was actually designed to achieve accuracies of just a few meters. Unfortunately, the accuracy of the system is purposely degraded by the U. S. Department of Defense using a system called Selective Availability. This system, which works in part by adding clock noise to the satellite broadcasts, reduces the accuracy of the system for the average user, but has no effect on special coded receivers used by the military. Differential GPS gets around this added noise through the use of a base station, which is set up at a fixed site. The GPS base station receives the information from each satellite, computes its position relative to the satellites according to the GPS system, and then broadcasts correction information to any nearby DGPS receivers. The nearby DGPS set computes its location based on the GPS signals and the corrections it receives from the base station. In this case, nearby means closer than about 200 km, a distance dependent on satellite visibility and ionospheric variations.

There are several interesting facts about DGPS. The first is that the U. S. Coast Guard is going around putting up DGPS base stations and beacons along the coast of the U. S. To my simple way of thinking this seems like one government agency paying lots of money to undo something that another agency is intentionally doing. The designers of the system have always claimed that the development of DGPS base systems was foreseen, but I still don’t understand the reasoning behind Selective Availability. Even more curious is the fact that during the war in the Persian Gulf, the U. S. military turned off the Selective Availability, making the full resolution of the system available to all users. They did this because they didn’t have sufficient military GPS receivers to go around. Instead they bought lots of commercial sets for their personnel in the desert. I’m certainly no expert on military affairs but if I was the boss I think I’d turn off Selective Availability, except in time of war.

There are other, even more fantastic forms of DGPS. The system I have referred to here is called pseudo-range DGPS, and is the simplest form. Another, more sophisticated form of DGPS, called carrier-phase DGPS, can provide centimeter-level accuracy. This is seriously cool stuff. At this time, carrier phase techniques are quite expensive, but they are beginning to find application in multi-antenna systems that can determine not only the location but also the orientation of a ship. This is more accurate on long time scales than the standard gyrocompass, and so can be used to reduce compass errors in ADCP measurements.

At the same time that GPS provides location, it can also provide very precise time information. The trouble is that in my experience very few oceanographers take advantage of this capability. I cannot tell you how many times I have seen an otherwise reputable scientist rely on the clocks in their computers (which they set from their wristwatches) for timing on experiments. Wristwatch time just doesn’t cut it when data from several systems need to be integrated together after the experiment. This is something that I can safely say you won’t fully appreciate until the fourteenth time in a post-test analysis where the only explanation for a discrepancy is a possible several minute timing error in one of the data acquisition systems. The point here is that synchronized timing is often needed between data acquisition systems within a lab, between labs, and between platforms. While some details of
clocks and how they drift are described in Chapter 6’s description of data acquisition systems, it is good to think about the overall need for time synchronization during the planning of an experiment.

To give you some idea of what I mean, I’ll relate two brief stories of timing problems that I have personally experienced. On one cruise we had difficulty with the interface between a gyrocompass and our Acoustic Doppler Current Profiler (ADCP). It seems that the scientist responsible for the system had no idea that stepper interfaces were notorious for drifting due to missed steps. After we realized that we had a problem, several of us scrambled to come up with a workable solution. We could post-test calibrate the ADCP data using the compass data from our meteorological system. In investigating this solution, we discovered that the programmer of the meteorological data acquisition system had utilized the system clock in the IBM PC, which was drifting like mad. This same system had a GPS time code going into it, but the careless programmer had decided to discard the GPS time data in favor of a clock that drifted due to his overuse of interrupts. In the end, the data were important enough that several weeks of effort had to be devoted to correcting the clock drift in the meteorological data stream by performing short-time correlations of the high frequency portion of the compass signal with the stepper output. Once the two data streams were synchronized then the met compass was used to correct the ADCP data.

My favorite timing story took place during a cruise on a Russian research vessel. When we first set up our equipment we installed a GOES satellite clock to synchronize our own systems. Our offer to provide these time signals to our Russian colleagues was initially turned down. Our Russian colleagues explained to us that this was a very modern research vessel and each lab contained a video screen that displayed a clock derived from a satellite time code entering into the central computer. I was very impressed with this setup, at least until we noticed that the video clock in our lab was about 5 seconds behind our satellite clock. When we brought this discrepancy to our colleagues’ attention their initial reaction was that our satellite clock must be wrong! It took several days to determine that the problem was in the central computer. When the computer experienced a large load, such as when acquiring CTD data, the updating of the clock was delayed, sometimes for several seconds. Thus not only was the video clock late, but it was late by an amount that depended on the computer load. By this time our colleagues were convinced that they should use our clock to time their instruments. When the signal was run to a forward lab, the scientists there at first objected that it differed significantly from their clocks. It turned out that their entire lab had been synchronized to a wall clock that differed from real time by about 15 minutes! To this day I kid my friends who were in that lab about the forward lab in the ship being in a different time zone than the rest of us.

One final comment about time, and that is units. When you make a scientific measurement of length you use meters. When you measure mass you use kilograms. Likewise there is only one way to measure time on a scientific experiment, and that is UTC. (UTC is essentially French for Greenwich Mean Time or GMT. It has always struck me as funny how the French have a different word for everything.) Local time is not acceptable. The use of local time is certainly a sign that timing has not been taken seriously on an experiment.

What to pack

Packing for an experiment should be a nerve racking experience. You read that sentence correctly. While packing, you should be constantly worrying whether you are taking the right stuff. After all, when you get out on that ship, the nearest Radio Shack might as well be on Mars. (Actually I think several of the people who work at my local Radio Shack spend their spare time on another planet, but that’s another story.)
In this section I’ll provide a few hints to help insure that you take the things that you need. The key in all of this is to focus your planning on your possible needs at sea.

**Packing lists**

When I first went to sea, I just packed up those things that I thought I’d need, and I went. I was saved from disaster in these initial expeditions by colleagues from APL, who were better prepared than I and could afford to lend me supplies, tools and equipment. It slowly sunk into my skull that I needed a system. We’re not talking quantum physics here. I just started making a list of the things that I use on an experiment. I began by listing all of the items that I had taken on my previous experiments. To this I added all of the stuff that I had borrowed or used from others. I then added the new items that I knew I would need for my upcoming experiment. I worked and worked on the list, making sure that it included every item that I might possibly need. I used this list to guide my packing for my next experiment.

Things went extremely well on my first experiment using my list, in large part because I had planned and packed so well. Still there were some items I had overlooked, that I ended up needing during the experiment. I kept a list at the end of my cruise notebook of all of these items. I also added items to this list that I saw other scientists using on our cruise that I thought might be handy on future tests. After the experiment ended I added these items to my Master packing list, which gets longer and longer after each experiment.

My packing list was in fact too long for the next experiment that I went on because of the limited nature of my participation in that particular experiment. I thus added the new items that I was going to take on that cruise to my Master list, duplicated the Master list and then edited the duplicate list deleting those items that I didn’t need. I now do this on every experiment. In this way my Master list grows and grows, reflecting the items that I have used on nearly all of my experiments. When an individual experiment arises I add the new items to the Master list, make a copy and then delete the items I don’t need from the copy, which is now my specific packing list for that experiment. This forces me to go over every item I have ever found useful before every experiment helping to insure that I don’t forget anything. This sounds tedious, and it is, but the system works well for me.

The problem generally is starting such a system. Here is where I can help. I have included a commented packing list as Appendix C of this book. This should help you get started with your own Master list, and may give you some good ideas about things that I have found useful on my experiments. I will also admit to an ulterior motive for including this list – it is a blatant attempt to get this book onto the New York Times bestseller list. After all, what could be more exciting than reading someone else’s personal packing list?

**Expendables**

It’s hard to do science without pens and paper. Expendables should be an important part of your packing list. When planning your usage of expendables remember to plan for the unexpected. Someone else may have forgotten to bring rubber bands, which prove essential for the repair of a vital instrument. Everyone on the ship may want copies of your cruise log, straining your meager supply of paper. Your scissors, through an act of spontaneous evolution unimagined by even Darwin himself, may grow a set of legs and walk out of your lab. If I can partake of a Gump-ism, spares are good.
Again, I’ve included a separate list of expendables that I take on experiments in Appendix C. The quantities shown should be adjusted to meet the needs of each particular experiment, but it can be a starting point for your own list.

**Tools**

The only tool that some mountain gorillas use is a short, thin stick to get ants out of hollows in the trees. While this seems to work well for the gorillas, you may aspire to a slightly higher level of professionalism in your career. If this is the case then you’ll need a lot more tools than the gorilla uses. (Although I don’t want to slight the utility of a short, thin stick in many at-sea circumstances.) I haven’t included a full list of the tools that I carry into the field, because your list will necessarily be different and I felt I could only pad the length of this book so much. The important thing though is to take what you need, to take what you might need, and to take what you don’t think you need. If this sounds like I’m suggesting you over-pack, you’re getting the point. Tools typically don’t take up a lot of space. They are heavy, so you’ll be cussing me during the onload and offload, but when you find that the automotive break adjustment tool in your toolbox is the ideal gizmo for working on your CTD, you’ll thank me.

I usually pack a large commercial-quality roll-on toolbox packed with heavy tools. I also take a smaller toolbox with electronic tools, soldering irons, etc. Finally, think about taking some small tool bags for carrying a few tools out onto deck or out on a small boat for repairs of buoys. Let your needs guide what you take, but don’t forget anything.

**Instrumentation and spares**

The next major things to pack are your instruments. My advice here is to pack them well, always take copies of all of the documentation that you have, and take spares, and lots of them.

Documentation and spare parts are the keys to repairing equipment in the field. Anything can be repaired eventually. It is just that without proper documentation, including schematics, equipment repairs may take several orders of magnitude longer. Spare parts are also critical. Try to carry spares for all expendable items such as batteries, o-rings, and seals, as well as any delicate or exposed sensors that might get broken due to handling. Major subsystems and power supplies are other good items to spare. Finally, if you can afford it, spare instruments are great to have along. Even if the spare instrument is not of the same quality as the main instrument, it may make the difference between success and failure.

**Personal Gear**

Telling you what to pack for your personal gear is a bit more difficult. I have a commented list of the things I take to sea, but your needs will likely differ from mine. Still, it is best to anticipate your needs if at all possible.

Drugs - I’ll admit here and now that I would not have become a sea-going oceanographer if it was not for the ingestion of certain drugs while I am at sea. (No, not those kinds of drugs!) In particular, I use motion-sickness drugs to combat the nausea of sea-sickness. While I won’t recommend one drug over another, an overview of available motion sickness drugs, both prescription and over-the-counter, can be found in the section on sea-sickness found in Chapter 4. In addition I always take along some aspirin for headaches, some antacid for heartburn, and some non-drowsy formula cold tablets, just in case.
Clothing - Use common sense and take clothing that fits the season. Remember that early morning watches can get quite chilly, even in warmer waters, so it’s always good to take along a jacket or sweatshirt. In colder weather remember that layered clothing preserves warmth by trapping air. It also makes it easier to adjust the amount of insulation you need by removing individual layers. Ships are typically dirty places and major clothing hazards, such as grease, abound. For this reason, I’ll take at most one decent set of clothes on a cruise for use in port. The rest of the time I wear old jeans and t-shirts. The idea is to be able to discard your clothes at the end of the cruise if you have to. Remember that you’ll be working closely with others so don’t take clothing which is too tattered, suggestive, or immodest. A certain relaxed decorum is the accepted norm.

Shoes - A second pair is a good idea, in case your main pair gets wet.

Toiletries - Bring your own soap, shaving cream/razor, and other assorted stuff you need to prepare yourself for each day. These are not available on a ship, and it’s rather embarrassing to try to borrow a colleague’s toothbrush.

Personal safety equipment - As I have discussed before, I like to take my own safety gear on cruises. It is a bit more professional and it avoids the problems of people using my stuff. My typical list includes: steel toe boots, hard hat, personal flotation vest, and work gloves.

Flashlight - I usually take a small personal flashlight on cruises to get around on deck at night. Research vessels can often be extremely dark at night, so be prepared.

Alarm clock - Personally I use my watch, but don’t forget a more substantial alarm clock if you are heavy sleeper. It is worth mentioning that most motorized AC clocks will not work well on board a ship. While the 60 Hz (or 50 Hz for our more-civilized colleagues) AC power coming out the plug in your home is tuned to the proper frequency within ridiculously high tolerances, the AC power on a ship runs at somewhat arbitrary and chaotically varying frequencies depending on the number of waffles being made for breakfast and other, less discernable, factors. While the ship’s power is good enough to bake a casserole, it is not good enough to run the timer on the oven. My advice is to stick to quartz crystal clocks if you want to wake up on time.

Baseball or knit watch cap - A hat should be a requirement on all cruises. In sunny climates it can keep the sun off, and in cooler climes it can keep you warm. Furthermore, if you end up in the water, a hat can significantly retard the heat loss from your body, increasing your chances for survival. In warm weather I prefer a baseball cap, just be aware that they do have a tendency to blow off your head while under way.

Sun block lotion - To steal a line from Woody Allen, I don’t tan, I stroke. Sun block is a necessity in sunny weather. Look for an SPF rating of 30 or more.

Rain gear & boots - Somehow I don’t mind getting wet as much when I am at sea, but rain gear and boots are still nice to have when the weather turns nasty.

Washcloth - This may seem like a trivial thing, but I like to use a washcloth in the shower, and many ships don’t provide them. Be forewarned.

Flip flops - Sometimes these don’t get out of my duffel bag, but on some cruises they are great for going to and from the shower. Otherwise, it is not a great idea though to
wear sandals or flip flops around the ship because of the danger to your feet. They are nice though for use on those ships where the showers are located outside of your room.

Deck chair - A few years ago I invested $60 in a deck chair that folds into an extremely small space. Now, on every cruise, people make fun of me at the beginning of the cruise when I unfold my deck chair. By the end of the experiment, though, I usually have to fight to get to sit in my own chair. This is one of the best $60 investments I ever made.

Personal entertainment - This is a must with me, even though I am usually swamped with work on each cruise. I find that some music, books and computer games help fill the time. What you bring along for entertainment is your own business, just remember that not everyone will share your tastes. For example, I usually take along a CD player, an assortment of CDs and a small set of speakers. I always ask permission before playing any music through the speakers and if even one person objects I use my headphones. I also make it a point to share my system with others within my lab, so that we can each listen to music that we enjoy. Computer games are also great, just don’t let them get in the way of your work. You should also come prepared to use headphones on your computer games as the noise of most games may drive others crazy.

Items that are usually supplied by the ship include sheets, pillows, blankets, towels, cleaning supplies, toilet paper and laundry soap. You should always check first though and take an item along if you are in doubt. Remember that your personnel storage space may be limited. For that reason you shouldn’t carry hard-sided luggage on board, but instead should opt for an inexpensive duffle or sea bag. They can double as a dirty clothes hamper and take up no space when empty.

Travel

Inevitably you’ll need to travel to get to your on load site and from your offload site. You should take some care in planning your travel. Questions to ask include:

When will I need to be on the ship?
When will the ship return to port?
How certain is the schedule and what are the possibilities for change?
Will I need to hand carry equipment or data either to or from the ship?
How much time will spend in port?
Can I stay on the ship or do I need a hotel room?
How much money will I need for living expenses?

Make your travel arrangements well in advance and double check them prior to departure. Allow plenty of time at airports. You don’t want to miss a cruise because you got bumped from an aircraft flight. If your trip includes a stop in a foreign country then you should consider a whole host of additional questions:

Will I need a passport or visa?
How long before my trip do I need to apply for a visa?
Do I need any special shots or medical precautions to travel to this area?
What dress is acceptable in this country?  
Is it better to use traveler’s checks or cash?  
What exchange rates can you expect and what is the cost of living?  
What are the customs regulations regarding transport of equipment/data?

It is important to start asking these questions early. Visas can take 6 to 8 weeks. Foreign embassies are usually helpful but unmoved by pleads for special consideration, especially when you could have planned ahead.

Before departing on travel, it is a good idea to leave a complete itinerary and a copy of your passport with your office and home. That way people can get hold of you in transit in case schedules change, or can help out if you happen to lose your passport while overseas.

It is also best to keep reservations open ended and changeable, at least to the extent possible. You don’t want to go overboard with this though. I’ll usually compare the costs of getting an unrestricted airfare, allowing me to freely make any changes to the schedule, to the costs of changing the schedule on a nonrefundable ticket. I find that it is usually cheaper to buy the nonrefundable, supposedly nonchangeable, ticket and then pay a $50 or $100 fee to make a change later if you must. Just be careful to know the terms of your reservations and don’t be afraid to ask questions of your travel agent.

On load

So now you completed all your test planning, you have finished your shipping lists, and are all set to go. The final step is actually getting your gear onto the ship. This is the part that I hate, but it is necessary and in some ways your onload may set the tone for the cruise.

The first step is to pack your equipment carefully. I have been on several experiments where major instruments arrived on the dock broken due to a shipping mishap. Several years ago there was a cute television commercial for a luggage manufacturer, featuring some chimpanzees acting as airline baggage handlers. The commercial was quite funny, but in today’s competitive environment, shipping companies have progressed way beyond this common stereotype. In today’s fast-paced world of shipping, the chimpanzees are now driving forklifts. Your only hope is to pack well. This means boxes in boxes, lots of padding cut to fit, and solid outer containers. There are lots of good commercial packing containers on the market, so I suggest you invest in some tough containers.

Once your equipment is packed you have to ship it to the onload port. Shipping is always a precarious venture that typically relies on an inordinately large number of things going right for your shipment to arrive safely and on time. As in almost any human endeavor I have found it best to assume that the system will break down at some point. So I routinely expect that my shipments will take longer than I am told. I expect that they might get lost or trapped in customs. I expect that they will be left out in the rain for some period of time. The best you can do is pack well, track you shipment as closely as possible until it reaches its destination, and pray.

Once you and your equipment arrive at the ship, the onload can begin. Well almost. First you’ll need to check out the ship. Ask for a brief tour of the vessel, paying particular attention to your assigned room, lab and deck space. You’ll also need to check that the proper support is available for your onload of equipment. This might include a forklift, hand trucks, cranes, welding services for deck cradles, etc. Finally, you’ll likely need help from
colleagues or crew just carrying your equipment on board. This is where you can get off to a
good or bad start. Most people will be glad to help you if you ask nicely, work along side
them, and reciprocate the favor by helping others.

This is the time you should start building your relationship with your colleagues. Your
primary responsibility is to get your equipment on board and get it working. At the same
time, this is the responsibility of all of the other scientists and engineers involved with this
cruise. Some time spent helping others can more than pay for itself in good will later in the
cruise. If you finish your work, or are needed temporarily to help someone else, don’t
hesitate. I always hate seeing people set up their equipment and then run off when others are
working. It is a certain sign that the scientist is more interested in their own work than in the
success of the cruise as a whole.

This is also the time to start building your relationships with the ship’s crew. Remember
each time that you board a new ship that you are walking into someone else’s home. You
should treat the crew with respect and realize that they also have a lot of duties to get ready
for the cruise. Getting off to a bad start with the crew can lead to problems for the entire
cruise, so be on your best behavior.

One colleague I know tries to get off to a good start with the crew, at least in warm
weather, by taking a cooler of soft drinks on board with him during the onload. Offering a
cool drink to the crew after they have been working may seem like a cheap bribe, but it is a
small gesture that usually goes over well.
**Planning Checklist**

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<th>Agree upon experiment objectives and methodologies within a written science plan.</th>
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<td>Come to complete, mutual and explicit agreement on all collaborations.</td>
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<td>Make sure responsibility for each instrument is assigned to a single individual.</td>
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<td>Plan for adequate scientific supervision of technicians and graduate students at sea.</td>
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<td>Write and agree upon a detailed test plan that should address:</td>
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<td>- Scientific overview</td>
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<td>- Experiment overview, including schedule</td>
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<td>- List of participants, platforms and instruments</td>
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<td>- Progressive detail of operations from platform to instruments, including coordination of platforms and groups</td>
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<td>- Communications, including frequencies and schedules</td>
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<td>- Navigation and timing</td>
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<td>- Safety</td>
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<td>- Contingency plans</td>
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<td>- Command organization</td>
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<td>- Ship resource allocation</td>
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<td>- Onload/offload scheduling and resources</td>
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<td>Establish a chain of command for the experiment</td>
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<td>Allocate resources fairly among the various investigators</td>
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<td>Coordinate activities of various platforms, groups, and instruments</td>
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<td>Coordinate onload and offload activities including shipping and ship/pier support</td>
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<td></td>
<td>Establish a communications plan including voice, fax and data; establish frequencies and schedules</td>
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<td>Be sure those communicating understand difficulties and proper communications etiquette</td>
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<td>Plan overall experiment navigation and timing, setting requirements based on overall experimental objectives</td>
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<td>Pack equipment, tools, supplies, and personal gear. Insure everything necessary is packed by using packing lists</td>
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<td>Make and double check all travel arrangements</td>
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Chapter 3. Safety

Rule 1. Safety first.

This is the one absolute rule in this book. Safety must be your primary concern during a cruise. It must be the primary concern of everyone on the research vessel. There can be no bending of this rule. I have argued that sponsors may have millions of dollars riding on the success of a sea cruise. I have argued that your career may well depend on your success. These considerations are important, but they in no way compare with a human life. I am not an insurance underwriter and I do not think a price can be placed on a human life. When compared against any other consideration that you may face in working at sea, safety should always come first.

If those arguments don’t sway you; if you are a bottom-line kind of person and believe that your data will change the course of history, that your data may be worth an injury if not a life, then think again. Any serious injury will lead to the immediate termination of the cruise. The ship will turn around and head for the nearest port. Your instruments may be left adrift at sea and your data opportunities will be lost.

In saying these things, I know that everyone reading this book will object, ‘That's not me. I would never place myself or someone else at risk just to get some data.’ Well once you start going to sea you’ll find that you’re faced with such decisions all of the time, and on some occasions you’ll be sorely tempted to bend the rules. Even I'll admit that most of the time you can break the rules and get away with it. You must understand though that it is simply not worth the risk. When the temptation arises, you must resist and put safety first.

I recently had a conversation with a biologist friend who had been doing sampling work in a northern lake. He explained to me both the rules of diving and how he would stretch them, just a bit, to pull those last few samples from the frigid waters. He told me of one time when his diving partner had tired to the point that he couldn’t go any further. My friend dove solo to retrieve the last sample. He shook his head about the incident and admitted it was dumb thing to do. He survived and there was no damage done, but the fact that this bright, intelligent scientist would put himself at risk for a single sample out of hundreds was striking. Much of our self worth gets tied up into our work. The importance of our work tends to become inflated in our own minds to the point that it can cloud our judgment. You must guard against this.

As a counterpoint, consider the speed limit on your local highways. In my area, the speed limit is 55 miles per hour (I apologize for the units). This is the maximum safe speed as determined by the authorities in my area. Does this mean I never exceed 55 mph? Hell no. (In case my insurance company reads this I won’t tell you how fast I do drive.) After all, under good conditions virtually all of the roads I travel can easily support speeds higher than 55 mph. While I know that statistically the accident rate increases at speeds above 55 mph, I trade off some margin of safety versus the extra time I save by traveling at a higher speed.

Many decisions that you face on board ship will be like the one we each face when deciding how fast to drive. For example, you may have to decide whether to wake someone who over slept or just bring a buoy onboard with one less person handling lines on deck. In calm seas the decision is easy. As the seas build your margins of safety are reduced. Where do you draw the line?
In each instance you'll have to make the decision individually. My argument is that if you do err, err on the side of safety. Take more care than you would on land. Be aware of the alertness and mental condition of each person in the crew. When things go smoothly, deployments and recoveries are easy, and even a little boring. Boring is good. Accidents typically occur due to a chain of events and you want to be sure that everyone is certain of their responsibilities and alert to problems as they occur.

Another aspect of safety that you need be aware of is that not everyone thinks of safety in the same way. I was at a Navy port one time preparing for an experiment when some investigators from another institution launched a small research catamaran of less than 5 m length into the water for the first time. They had mounted a guard’s shack on top of this catamaran and filled it with instrumentation racks. When the vessel was lowered into the water it nearly sank to the top of the pontoons. With a scientist on it, the hull would actually partially submerge. When I, playing the part of Richard Dreyfuss in the movie Jaws, suggested that the vessel was a bit overloaded, I was told that it would be fine. After all they were only going a few miles off shore!

These investigators had no concept of boat safety and were going to unknowingly risk their lives to gather data. After being blown off by the investigators I did not hesitate in raising my concerns with the APL test director and the Navy’s test liaison and safety officers. After a brief inspection, much of the equipment and two scientists were removed from the vessel (and here I use the term loosely) and an experienced pilot was added to the crew list. In the end, these investigators ended up getting their precious data but at a significantly reduced risk to life and limb.

To me the surprising thing about this story, is that these investigators, who I think were being so dumb about safety, are very smart guys. I respect them as researchers, but intelligence and skill in research do not assure common sense when it comes to safety. We all have our blind spots.

Training

The keys to avoiding accidents are training and awareness. People need to be trained in the do’s and don’ts of all manner of ship activities. At the same time, they need to be vigilant and aware of conditions around them. I liken this requisite awareness to the capability of a football quarterback to see the entire field. By this, I mean his ability to perceive and quickly evaluate the total picture of what is going on about him.

Let me be specific. I once hired a technician to work on what was his first and last cruise. We carefully reviewed safety procedures and it was clear he understood that he should never walk under an object lifted above the deck. Still, several times during the on load he would simply stand under a load while it was swung over him. I pointed out his error and he promised to be more careful. On our second day at sea, we began deployment operations. I was in the lab when one of our engineers came in to complain about our new technician. I walked out onto the deck to see him standing obliviously under a 100 kg buoy suspended 3 m off the deck. After I removed him from the deck, I threw a minor fit. I asked him what he had been doing. He said that he just wanted to help out if he could. He wasn’t even aware of the buoy that was suspended over his head. He explained to me though that he was confident that the lifting strap and bridle would hold – he couldn’t see why I was upset. At this point I had calmed down enough to quietly explain to him that he was banned from the deck of the ship during all deck operations. He thought this was unjust, but I explained the reasons for the rules, I explained that I expected everyone in our party to follow those rules, and I explained that his indifference to those rules had placed both his safety and the expedition in jeopardy.
I am not certain awareness can be taught. Everyone knows that you are not to stand in the bite of a line, but this is quite different than recognizing, while working to deploy a buoy on a heaving deck, that you are standing in the bite of a line. (A bite is an open loop of line. If you step into the loop, and the line goes taught, it can tighten around your foot or leg so that you cannot get loose.) Menard put it in this way:

...A more common problem is that inexperienced scientists have unjustified faith in the reliability of winches and other ship equipment. Consequently they do not take steps to avoid improbable misadventures and accidents. The experienced oceanographer takes precautions to avoid any conceivable equipment misbehavior and expects that highly improbable events will surely occur. One time the power lead to the main dredging winch on one of our ships was being repaired in the engine room. No one was near the winch, and a colleague and I were leaning against the after rail awaiting developments. We were directly on a line between the dredge on the deck and the sheave on the end of a boom through which the dredging wire led to the winch. I remarked "Max, no one is near that winch, and I don’t see how it can start. However, if it does, the dredge will be pulled across the deck, pin us against the rail, tear it away, knock us over the side, get jammed against the sheave, break the cable, and fall on top of us in the water. It seems to me that the view is just as good six feet over there where we are not on a line with the winch." We idly moved over, exchanging sea stories. A moment later, the winch started to haul in even though no one was near it. The dredge moved across the deck, tore away the railing, jammed in the sheave, the wire broke, and the dredge disappeared into the deep. We stared at these nearby and dramatic events with some amazement. Shortly, the winch operator climbed out of a hatch leading up from the engine room and after stopping the winch explained that he had shorted some wires down below.

One thing that I do before each and every cruise is to have the members of my party read and review a copy of the APL safety manual. While the people who have been to sea with me before always groan at having to reread this manual for the n\textsuperscript{th} time, I think a safety review prior to each cruise is a big plus. I reread the safety manual myself before each cruise because I find its advice useful.

I am sure that other organizations have their own safety manuals. While the APL safety manual, which is excerpted in Appendix A, is not meant to be a complete guide to at-sea safety, it does provide a number of useful guidelines. I have included excerpts from the manual here in the hopes that you will read it and use it prior to your cruises. These are not arbitrary rules, but are based on years of experience by people at APL and elsewhere. The author of the APL safety manual drew heavily upon standard references in the field. Not all of it will apply to any given operation, but read it all none-the-less. You never know when following these rules might save someone’s life.

The other thing that I do just prior to each cruise is to have a safety meeting with all of my personnel. I make it clear that my number one priority is to have a safe cruise and that safety supersedes all other concerns. We review the most important safety rules and discuss any questionable activities that we anticipate during the cruise, including all deck or small boat operations. I finish by emphasizing that safety has to be everyone’s concern. I don’t want anyone doing anything that they feel uncomfortable with and I explain that there will be no negative repercussions for voicing safety concerns during the cruise.
Deck Operations

Deck operations include all aspects of lifting and moving objects on the deck of a ship. Deck operations typically include the use of cranes, A-frames and winches to lift objects onto the ship during on load, into and out of the water during deployment and recovery operations, and off the ship during offload. Deck operations, and deployment and recovery operations in particular, are the most dangerous activities on ship. All participating personnel should be trained in the proper procedures for the safe deck operations.

The dangers from deck operations are several fold. First, cranes, lifting straps, and bridles have been known to break releasing their load to the deck. I have seen it happen and it is a terrifying site. A few hundred kilogram buoy falling from a meter height can do a lot of damage. Second, anytime you lift an object off of the deck of a rolling ship, that object will swing about. Tag lines are used to control the swinging of suspended objects, but a large swinging buoy can be dangerous to the crew and itself. Finally, most deployment or recovery operations involve personnel working near the edge of the deck. With the confusion of the moment, the clutter of a typical deck, and large swinging load, it is all too easy to lose someone overboard.

These dangers are reduced by limiting personnel involved in deck operations, establishing a clear chain of command for the operation with a single person in charge, planning all aspects of the operation, use of the proper equipment, and individual attention to safety.

Almost as an aside, Herman Wouk, who served in the Navy during World War II, wrote these paragraphs that well describe the confusion of deck operations in his famous novel, *The Caine Mutiny*:

“At four o’clock the minesweepers formed a slanting line, a thousand yards apart, and began to launch their sweep gear. Willie went to the fantail to watch.

He could make no sense of the activity. The equipment was a foul tangle of greasy cables, shackles, floats, lines, and chains. Half a dozen deck hands stripped to the waist swarmed about under the eye of Maryk, uttering hoarse cries and warnings larded with horrible obscenities as they wrestled the junk here and there on the heaving fantail. Waves broke over their ankles when the ship rolled, and water sloshed around the gear. To Willie’s eye it was a scene of confusion and panic. He surmised that the Caine crew were unfitted for their jobs, and were fulfilling the ancient adage:

*When in danger or in doubt, Run in circles, scream and shout.*

Despite the fact that later in the novel, Willie reevaluated his opinion of the efficiency of the crew in performing deck operations, I still find the description a vivid and apt one.

Rules of Deck Operations

The first rule of deck operations is that only those that are directly involved with the operation should be on the deck. All other personnel not directly involved with the operation should be well clear of the area. There are several reasons for this rule. First, it minimizes the number of potential victims, should something go wrong. Second, it maximizes the amount of free space available to those working on the deck to get clear of a falling or shifting load. Finally, it reduces the possibility of confusion.
Unfortunately these simple rules are not always followed. I was once involved in a search and recovery operation on a research vessel. The ship had lost an expensive CTD system in about 80 m of water and we were attempting to locate and recover the instrument. Everyone on board was anxious to help, and so when we began our search operation, everyone on board, including the cooks, were at the midship starboard station trying to help. The confusion and chaos was so overwhelming that I ordered the retrieval of the acoustic sensors we were using for the search and marched up to the bridge (at least the Captain was on duty) to ask for some order. After strict orders came down from the bridge that no one was allowed in the working area without direct orders from the Captain or the ship’s Chief Engineer, order was restored and the search continued. It is amazing how much confusion can be sown by otherwise well-intentioned people.

Confusion in deck operations is also minimized by establishing a strict chain of command before the deck operation commences. There must only be one person in command of the operation at any one time. I’ll refer to this person as the scientific deck officer. On APL cruises the scientific deck officer is normally not a scientist, but one of our senior technicians with the most at-sea experience. We have found that the scientists typically do not have the experience necessary to deal with all possible problems that might arise and that scientist’s judgments regarding safety issues are often clouded by their interests in the outcome of the operation.

Usually the scientific deck officer will have little else to do other than direct the others on the deck. This is because it is surprisingly difficult to direct others when you are wrestling with a 500 kg buoy on the end of a tag line. The scientific deck officer also usually has to have both hands free to give hand signals to the crane operator. The APL safety manual calls for a separate safety officer whose sole job is to monitor the safety of the operation. We usually give the scientific deck officer that safety role, which further restricts their physical participation in the operation. A final reason to keep the scientific deck officer free of physical responsibility is that if something does go wrong then they can either summon help or freely act to correct the situation.

While it is rare, it will sometimes be necessary for command to switch from one person to another during a deck operation. For example, when deploying a buoy, the scientific deck officer might have control of the operation while the buoy is over the deck, but that control may switch to the crane operator when the buoy is over water, well away from the ship. This might occur in situations where the crane operator would be in the best position to determine exactly when to lower the buoy into the water to minimize the possibility of damage. Such switches in responsibility need to be carefully planned and understood prior to commencing any operation.

This leads to our next rule of deck operations – every operation should be planned prior to commencement. All personnel should then be briefed on the overall operation and exactly what role they are to play in the operation. This sounds so military that it brings to mind the preflight briefings that you see in all those old war movies before the pilots go off on a bombing mission. While I don’t mean to imply anything quite so formal, the idea is actually the same. It is important in these operations that everyone is working together, understands their responsibilities and what to do in case of an emergency. In particular, we always discuss exactly what each person will do if the buoy gets loose on the deck (which is always more frightening for spherical buoys!) We then synchronize watches and off we go.

In addition to training and planning, it is important that all deck personnel have the proper equipment. On UNOLS vessels, as well as vessels used by APL, hard hats, gloves, and personal flotation vests are mandatory. People regularly complain about this requirement, but it is important. The biggest single complaint regarding the required equipment is usually about
the restriction of movement from wearing a personal flotation device. Despite these complaints, modern personal flotation vests are quite compact and do not present any significant hindrance to movement. On the other hand, the cheap lifejackets that are available for scientific personnel on some ships are atrocious in this regard. My solution is to take my own personal work vest on each and every trip. This way, if the ship has old bulky vests, I can work safely and still be comfortable. There is also a great advantage in having your own vest in that others won’t be readjusting the straps all the time.

I also take along my own hard hat, although I have never been on a ship that didn’t have them. It does add a bit of professionalism though to your operation when you show up with your own safety gear. And again, I don’t have to worry about adjusting the hat each time I go to put it on. One piece of advice though on the hard hats – don’t lean over the side while you are wearing one. I was on one cruise when the scientists lost five of the ship’s hard hats by looking over the sides at the end of buoy deployments. I don’t think the skipper was too happy about the prospect of explaining his losses to the marine department on his return!

These rules about organization and equipment are important, but the most important rule is a simple one: keep you eyes on the load. When a load is lifted above deck, you should always be aware of its location, attitude and velocity. People who don’t keep track of the load should not be on deck.

I was on a cruise once with a scientist who was directing the deployment of a small buoy with the help of a crane operator from the crew. Once the buoy had been lifted over the side, the scientist noted something about the buoy that was not quite right. He motioned for the crane operator to stop the deployment. The scientist then dropped his tag line, turned his back to the buoy, and walked away to get a tool. While the day was calm, the ship had some roll to it, and as I watched, the buoy began to swing. It finally collided with the side of the ship with a resounding thud. The scientist ran back to the tag line, got control of the buoy and directed the crane operator to recover it. While the damage was minimal, the scientist started to chew out the crane operator for letting the buoy bang up against the side of the ship. At this point I stepped in to point out that the crane operator had done exactly what he had been told to do, and that the scientist was at fault for letting go of his tag line and walking away. The moral of the story is to always think about what is going on during deck operations. A second moral is to not blame others, especially the crew, for your own mistakes. This I’ll discuss in more detail in the chapter on People.

Night and Heavy Seas Operations

As scary as I make things sound, daytime deck operations in calm weather are surprisingly mundane. From the viewpoint of safety, a boring cruise is a good cruise. Night time and/or heavy seas operations are a different story. When operating at night, all personnel should also carry personal safety lights on their work vests. Without a light at night, a person is almost impossible to find. Also more attention has to be paid to deck obstructions that are harder to see at night. Personnel checks should be completed before and after each operation to insure that no one was lost during an operation. I know this sounds silly, but before leaving the deck each individual in the deck crew should notify the scientific deck officer. We have yet to lose anyone on a cruise I was involved in, but on more than one occasion we have had to search the ship for personnel when they have wandered back to bed after a nighttime recovery without telling anyone.

Heavy seas operations are another matter altogether. Before any heavy seas operations are begun, the scientific deck officer needs to determine if the operation can be done safely. We usually avoid trying new types of deployments or recoveries during heavy seas because of
the increased risk of accident. Typically, when a smaller vessel is running in heavy seas, safety lines will have to be rigged and used. Safety lines run along the deck from one tie point to another. The deck crew wear harnesses with lines of a few meters in length that can be attached to the safety lines. The attachment is usually through a clip of some sort that will hold the line to the safety line, but will allow the clip to slide back and forth so the crew member can move along the deck, up and down the safety line. It is critical in these operations that you are attached to a safety line at all times. If you need to move from one line to another, unclip from one and clip back onto the other line immediately. The lines will do you no good if you are not attached to them. The second critical point is to remember at all times that you are on a safety line that could restrict your freedom of movement in case of an emergency. Thus keep your line clear of other lines at all times, keep it away from deck obstructions (cleats, protruding plates and the like), and keep an emergency retreat path in mind should something go wrong.

In any case, where you need to go out on deck at night or in heavy seas, it is a good idea to use the buddy system. That is you find someone to go outside with you to keep a watch on you while you are working. In this way, if you fall overboard, there will at least be someone there to notify the rest of the crew of your predicament.

**Tag Lines and the Control of Loads**

If you are working on a deck operation, odds are you will be holding a tag line to control the motion of a buoy. Tag lines are amazingly simple devices (you can’t get much simpler than a piece of rope), but I cannot tell you how many times I have seen scientists apparently mystified by how to work a tag line. So here is the number one rule of tag line operation: tag lines don’t work if you push on them, tag lines only work if you pull! In fact the whole idea is to maintain tension on the line at all times, using the opposition of forces to control the object. With multiple tag lines used on heavy objects, the lines should be spread about the object so that the opposing tension comes from pulling against your fellow crew. On lighter or longer objects with more of a moment arm, the opposition can come from pulling on the pendulum formed by the object and its support.

Let me say it again, tag lines don’t work unless you pull on them. Never let them go slack. The idea is to damp out the motions through the use of opposing force. On a calm day, invariably scientists will let their tag lines go slack because the load is not moving much. A few moments later, when the load gets to swinging from the gentle sway of the ship, they panic and have to pull with all their might to try to steady the beast. This is nuts. A little bit of tension applied at the proper times can go a long way to insure that the swaying never begins. Remember that momentum is mass times velocity. If the velocity is kept small then the momentum will be small.

Another critical point is to never work a tag line that is too short. At the maximum lift of the crane (which is the most dangerous point in terms of the object being dropped) you should be well away from the object. If the tag line is so short that you end up standing under the object then a) you are not doing much good in restricting the motion of the buoy anyway, and b) if the buoy falls your spouse will be able to live it up on the insurance money.

Another mistake I see nearly every newcomer make is to wrap the tag line around your hand to get a better grip. I did this myself when I first went to sea. It seems to be a natural instinct. My advice here is simple: don’t. When an object is lifted in the air, you must be ready for it to fall at any given moment. If a buoy fell into the sea with a tag line wrapped around your hand, you could end up doing significant damage to the railing of the ship as you are dragged through it and overboard. This would really upset the skipper as he’d probably
have to fill out a million forms explaining your dismemberment when he got back to shore. It’s not good to upset the skipper, so don’t wrap the line about your hand.

Finally, on our list of do’s and don’ts for use of tag lines, watch the tangle of line that will inevitably end up behind you. While your primary attention must be on the load, if the crane support failed, the line behind you could take you with it as it raced to follow the buoy. To sum it all up: be careful and aware, keep you lines taut, and act as if the crane will fail at any moment.

*The Most Dangerous Times*

There are two points of maximum danger during deck operations. Danger to personnel is maximum when the load is suspended over the deck, while danger to the instrument is maximum when it is suspended over, but not in, the water near the side of the vessel. These are important points to keep in mind for safety and success in deployments and recoveries.

A swinging load above a deck cluttered with people and obstacles can cause quite a bit of damage. The key is to keep things well controlled as I have described in the previous sections. If a load does manage to get away from you over the deck, then the solution is to set the load down onto the deck (but by all means, do not release it) to control its motion. This may break some instruments but it can prevent injury. I have seen smart crane operators do exactly this when the scientists let a load get away from them.

The funny thing is that the most dangerous time for people is not the same as the most dangerous time for the buoy. When a buoy is swinging above a deck, it usually won’t be in a position to hit anything other than a scientist or two, and a person colliding with an oceanographic buoy at a few meters per second does very little damage to the buoy. The most dangerous time from the buoy’s viewpoint is when it is hanging over the side of the ship, but is not yet in the water. Typical ship’s cranes do not have that much reach and thus a buoy can bang up against the side of a vessel if it gets swaying when it is over the side. Once in the water, of course, the water itself will dampen the motions of the buoy sufficiently where it is not a danger. The point here is to deploy and recover buoys as far away from the ship as possible AND to minimize the time that the buoy is out of the water and next to the ship hull.

On deployment, once the buoy is swung over the side, it should be lowered into the water as soon as possible. If you notice something wrong with the buoy after it has been lifted, it is usually best to put it back into its cradle to fix the problem. Don’t try to work on a buoy suspended over the side. It is a sure way to lose tools and instruments. (Believe me I have tried, and lost both. I have littered the ocean floor at a variety of test sites over the years with wrenches, screwdrivers and wire cutters. If you ever happen to come across a tool on the bottom when you are diving in the *DSV Alvin*, then it is likely mine.) On recovery, once the buoy is hooked, it should be lifted above the ship as soon as possible. This also minimizes the length of the pendulum and hence the buoy motions.

There is yet one more danger point to both people and buoy while the buoy is “safely” in its cradle. While it is not as severe a problem as during deployment, be aware of the damage that can be caused if someone accidentally walks into the buoy and bends or breaks a protruding sensor, connector or antenna. The best way to prevent this problem is to make the support cradle large enough to prevent people from walking too near the buoy.
Ship's Crew

I'll complete this section by briefly mentioning the ship’s crew. I have averaged just one sea cruise a year over the past several years. With an average duration of 10 days, that means that it takes me ten years to gain about one hundred days of at-sea experience. Most of the crew members that you will sail with gain this same experience in a single year. Most crew on scientific research vessels know more about the handling, deployment and recovery of oceanographic equipment than you or I will ever know. Listen to them. Seek out their advice. Give them a stake in your work by explaining to them what you are doing, by including them in your operational planning, and by listening to their input and suggestions. You may know more oceanography than they do, but they know more about working at sea. Only a fool would not avail themselves of such expertise.

Electrical Safety

Up to this point I have talked about mechanical safety, but there are other dangers for oceanographers at sea. Electricity and sea water don’t mix. (I think I once read this in a chemistry textbook.) Instruments today are getting smaller and run on less power, so that many operate from low voltages. Still dangers abound for the unwary or untrained.

For example, many CTDs and samplers utilize a 48-volt power supply for their operation. This 48-volt power is conducted to the instrument via a single wire with a sea water return completing the circuit. This works fine when the instrument is in the water, but when it is brought out of the water the 48-volt potential appears directly on the instrument case or electrode. This can be lethal. A good safety precaution is to connect a grounding strap to the instrument before handling it onto the deck. Unfortunately, this is one of those rules that is constantly violated within the physical oceanography community. Similar dangers occur with autonomous underwater vehicles, although I understand that many people within this community take the danger more seriously, and regularly use grounding wires.

I have been involved with the fabrication or repair of electronic devices out on deck during the outbound cruise to a test area more times then I care to admit. When using power tools on the deck of a ship, you should take precautions. Don’t work with power tools in areas subjected to splash or spray. Always use grounded receptacles and grounded extension cords. And avoid standing water on the deck.

Another potential source of danger arises on ship due to the differences between ship’s power and the standard power that we get back on land, at least for U.S. citizens. Within the U.S., the standard 120-volt AC plug has three prongs: two flat prongs for the AC current and one round prong for the ground. It turns out that one of those AC prongs is also grounded back at the main junction box, so only one prong should have a nonzero potential relative to ground. (If you look at a two-prong AC plug in the U. S., you’ll likely find that one of the AC prongs is a little bigger than the other. This difference enforces the polarity of the connection so that, for example, the chassis of TV will be at ground potential.) The U. S. system differs from European power where both AC prongs, on a three-prong plug, have 110-volt (rms) potential with respect to ground. The potentials on these two AC prongs are out of phase, so that the potential between them is 220 volts.

Ship’s power is almost always like the European system in that neither of the two AC prongs are grounded. This should make no difference for transformer isolated equipment, but it can become a hazard for equipment which is not transformer isolated. Such non-isolated equipment is required by electrical safety codes to be designed so that no portion of the chassis is accessible from outside of the case, and all exposed metal must be insulated from the
AC ground. Still, insulation can break down. Furthermore, when such a piece of equipment fails, you may be tempted to open it up to work on it. Be forewarned that this can be more dangerous on board a ship than back in your lab. If you are forced to work on a piece of non-isolated equipment, you should use an isolation transformer and check the chassis potential with respect to the hull prior to touching anything.

A few years ago I was on *Flip* when a colleague experienced dangerous problems with a non-isolated piece of equipment. My colleague was setting up the equipment to support a simple acoustic experiment. Acoustic transducers had been mounted on *Flip’s* hull prior to deployment. The setup used a pulse generator driving a high power audio amplifier which in turn drove the transmit transducers. Separate receive transducers were connected through a preamp to a data acquisition system. Since he was dealing with a high power system, and the transducers were underwater and unreachable, my colleague hooked his equipment up cautiously. He checked to insure there was no short between the transducers and ground. He connected the transducers to the amplifier and powered it up without any signal. He then checked the voltage levels on the transducers and all seemed OK. He finally turned everything off and hooked up the pulse generator to the input of the power amplifier. I walked into the lab just as he turned the switch on. Immediately the system began smoking, not a pleasant sight (or smell) on board a ship. Quickly the power amp was shut down. My colleague almost burned himself when he attempted to remove the coaxial cable between the power amp and the pulse generator. It was red hot and in fact was the component that had started smoking.

After some analysis and schematic reading it became apparent that the design of the power amp was at fault. The amplifier power supply was not transformer coupled, but instead ran directly off the AC line. When AC power was applied to the power amp, the input “ground” went to a potential of 60 volts above *Flip’s* hull and the output ground of the pulse generator. All of the ground connections were nice thick pieces of wire so who knows how many amps of current were forced through the outer braid of that RG-58 coax before the power was removed. To make matters worse, an inspection of the power amp indicated that it had been modified, which had the effect of making the entire chassis electrically hot. While this amplifier was marginally safe back in the lab, it could have easily electrocuted someone on board ship.

In the end, Tim Stanton of the Naval Postgraduate School came to the rescue to salvage the acoustics experiment. He replaced the deadly power supply in the power amp with a much smaller, but isolated, laboratory supply that someone else had brought on board as a spare. It turned out that the experiment was using very short pulses and a low duty cycle so the replacement power supply did not have to provide a tremendous amount of power.

The moral of this story is that you should know your equipment and understand how it will operate on the peculiar power distribution systems available on board ships. A lack of understanding can be dangerous.

Finally, I’ll make a comment about power transformers. I have had the opportunity to participate in a number of cruises on foreign research vessels. The AC on foreign ships is invariably 220 volts at 50 Hz. It is fortunate that more and more U. S. built equipment is capable of directly handling 220-volt power, either automatically or by throwing a switch. Still, there is some U. S. equipment that requires 110 volts. In these cases I always take along some 2:1 step-down transformers to convert the 220-volt power to 110-volt power. The point that I want to make is that when faced with these circumstances you should avoid using autotransformers, but instead should use full isolating step-down transformers.
The prototypical isolating transformer has two windings about an iron core. The primary winding, which is connected to the input, is electrically isolated from the secondary winding, which is connected to the output. Thus one side of the output can be grounded without grounding the input. An autotransformer only has a single winding, but with a center tap. In the case of a 2:1 step down autotransformer, the input voltage is applied to the two ends of the winding and the output is taken from between the center tap and one end of the winding. Thus the input is not isolated from the output and grounding one side of the output may act to ground one side of input. Autotransformers are popular for voltage conversion because they are cheaper to make and weigh less than a full two-winding transformer. Despite these advantages, autotransformers should not be used on board ships, because grounding one side of the power distribution system on a ship is not advised.

![Transformer Diagram](image)

While ideally you should use transformers designed to operate off of 50 Hz, these are usually hard to find and therefore expensive. While I am not recommending this to others, I have found that good quality 60 Hz transformers can be used at 50 Hz as long as they are operated well below their maximum rated current specification.

Laser Safety

Another major personal concern of mine is laser safety. Working in the field of ocean remote sensing, there are numerous systems that use lasers. I have been involved in two separate programs where investigators with laser-based systems assured everyone that the systems were eye-safe, only to find out later that they were not. One investigator claimed that his system was eye-safe because of the statistical rarity of the nadir-pointed beam actually reflecting off of the ocean surface and hitting someone in the eye. Our laser safety officer at APL told me that while statistically this might be a rare occurrence, it would take only a single short pulse from this system reflected from the surface into your eye to do serious damage; damage that would likely not be felt until years later. This scared the hell out of me. Needless to say this system was not allowed to operate during our experiment.

In the second case, a scientist from a small company convinced one of our sponsors to support their measurement of surface currents from shore by laser ranging to some cheap plastic buoys deployed in the near-shore environment of the coast of California. I personally did the laser safety calculations, and then had them double-checked by our laser safety officer. The calculations showed an eye-safe range of 200 m, which was deemed adequate for our operations. Just before the test was to begin, the laser safety officer from the Navy base where we were operating, came to see me. After introducing himself he began to chew me out about our unsafe laser operations and the inadequacy of our test plan. I objected that I had
written the plan and done the calculations. I explained that the laser eye-safe range was 200 m and that no one would be within 1 km of the laser. The laser safety officer was unimpressed. He had just returned from the laser site where he had measured the laser power directly. His calculations indicated that the eye-safe range was 2 km! It turned out that the laser scientists had discovered that they needed more power to see their targets, so they just opened up their optics to increase their power. They weren’t going to tell anyone about it because they were afraid we would shut them down. It is amazing to me that normally sane people would risk someone else’s eyesight for a bit of data. I ended up throwing a fit that was heard back in Washington, D. C.

Hopefully after my little laser-safety diatribe you’ll be forewarned. We use low power lasers for a lot of things and they are incredibly useful and safe. I just have problems with the higher-power, short-pulse variety. I also find it amazing that while I can’t buy or store explosives legally, anyone with money can buy a laser that can seriously damage eyesight. I once saw a 2 W laser waved about a room by a high school student at a science fair I was judging. After I confiscated the system from him for everyone’s protection, he explained that his rich uncle had bought it for him. Simply amazing.

Radar Safety

I happen to do a lot of work with radar remote sensing in my career, so radar safety is another topic of importance to me. Being in the field has led me to realize that everyone should take heed of shipborne radars. Every ship has at least one navigation radar and you need to be aware of the dangers of strong electromagnetic fields.

The effect of low level electromagnetic radiation on humans is a topic of some controversy. I am not qualified to get into that debate. There is no debate though about the dangers of human exposure to high-level electromagnetic fields. Modern ship navigation radars create such fields within a few meters of their antennas. These radars are usually mounted on the mast above the bridge, and their antennas are extremely directional. So it is usually safe to stand beneath the antenna. Just be certain that all radars are turned off if you go aloft to mount sensors. The electric fields near the communications antennas can also be quite intense, so unless the transmitters are quiet, stay away from them as well. You usually have to notify the officer on duty when you are climbing above the bridge anyway, so just try to be safe.
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<td>Force everyone in your party to re-read your institution’s safety manual, Appendix A of this book, or some other appropriate safety manual</td>
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<td>1</td>
<td>Conduct safety meeting just prior to cruise</td>
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<td>Keep aware at all times while on board</td>
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<td>Continue to perform safety training on board</td>
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<td>4</td>
<td>Anticipate equipment failures and make contingency plans to keep everyone safe</td>
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<td>Keep loads low to the deck wherever possible</td>
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<td>6</td>
<td>Make proper use of tag lines, and never wrap a line around your hand</td>
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<td>7</td>
<td>Keep deck crew to a minimum</td>
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<td>8</td>
<td>Use proper safety equipment</td>
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<td>9</td>
<td>Don’t go out on deck alone at night or in heavy weather</td>
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<td>10</td>
<td>Never stand under a load</td>
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<td>Be aware of the dangers of ship power</td>
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<td>12</td>
<td>Be extra careful of lasers and radars</td>
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Chapter 4. Test Conduct

In this chapter I’ll try to pass on some of the rules that I have learned in actually conducting an experiment. Whereas I will be discussing details of instrumentation, data acquisition and personnel in later chapters, this chapter covers the more general aspects of conducting a successful experiment at sea.

Professionalism

You should always act professionally in the field. Professionalism does not mean rigid, unerring, or humorless, as some seem to think. Instead professionalism means that your primary focus should be on obtaining your data with an absolute regard to human safety, a prudent regard to the safety of the instrumentation and the minimal possible inconvenience to others on board. This is often easier than it sounds.

On my first cruise as a graduate student two separate incidents occurred which have taught me a lot about professionalism. In the first, I was aware going on to the ship that graduate students were not typically held in the highest esteem by the crew. Because of this I went out of my way to make friends with a few of the crew members. I got to know one crew member, who was actually a few years younger than I was, reasonably well. (I worked for a few years before going on to graduate school.) On one early morning shift, when everyone else was asleep, we were sending the CTD (Conductivity - Temperature - Depth probe) down to the bottom – an operation that took at least 30 minutes. I was on watch at the CTD station and my friend on the crew was operating the winch. I was bored so I walked out the door to the winch station to say hello. My friend just kept his eyes on the cable being paid out and told me that he was busy. That was ridiculous, I replied, it will take at least another twenty minutes for the CTD to reach the bottom. Even so, I just wanted to chat. Again the crew member told me he was busy, and rather brusquely suggested I return to my station. I left quietly, but I was offended by his abruptness. I thought we were friends.

It took me a few days to understand that he was doing his job and that my interrupting him was wrong. If there had been some problem with the cable while the winch was paying out, then he was expected to respond immediately. A failure to respond to a problem quickly could have cost the expedition the use of the CTD or winch and would have definitely cost my friend his job. Ignoring me, and even being rude to me as he did, was in fact the height of professionalism.

The moral of this story was struck home several years ago when I had the privilege of working on a Russian research vessel. This ship was one of the finest research vessels that I have ever worked on, and working with the crew and scientists was a joy. The Russians, though, had a different view about winch operations than we in the U. S. Here, we have winch operators, like my friend from years before, and the scientists are not allowed to touch the winch. On our Russian R/V the instruments were thought to be so valuable that only scientists were allowed to run the winches. Personally I think this is a mistake. While the typical scientist’s brain may be the size of a small planet, their attention span when performing a boring, mechanical operation is more typically that of a small rabbit. After all, there are a million things more interesting to think about than running a winch.

Sure enough, during our cruise, one of the scientists actually left the winch while the CTD was being brought up to the surface. One of his colleagues had asked him a question, which I am certain was very interesting, and he walked away from the winch to answer. By the time he got back to the winch, the CTD had come out of the water, arisen to the pulley on the
swing-out arm, broken the cable, and fallen back into the sea. He and his research group were devastated. A few minutes after the incident, and after a good chewing out by the captain, he told me that his career was over. He explained that normally he would be expected to pay for the lost equipment, but the cost of the lost equipment, an amount that I guessed to exceed $40,000, was more than he would make in his lifetime. Despite his trepidations, the story had a good ending. The third mate had the common sense to mark the position of the accident and at the end of the experiment we were able to recover the CTD in 80 m of water using a specialized echo sounder and remotely operated vehicle that were brought on board for this purpose. In the mean time we used a backup sensor that I had brought on board just in case it was needed.

In stark contrast to the professionalism that my crew-member friend from my first cruise exhibited, I pulled one of the stupidest stunts of all times later on that same cruise. It is not something of which I am proud. And though I got away with my recklessness, I thought I’d share the story as an example of non-professionalism to the n-th degree.

After a week at sea, everyone begins to get tired and worn down, especially the people new to at-sea work. (You can hear my excuses already.) In any case, it was 3 am one night late into the cruise and I was terribly bored. I was at the CTD station monitoring the descent of the CTD. The CTD had a pinger on it that periodically produced an acoustic pulse. This pulse traveled up to the ship, where it was recorded on the echo sounder. At nearly the same time, some portion of the pulse also traveled a second path down to the bottom where it was reflected back up to the ship. The difference between the arrival times of the direct and reflected pulses told us how high the CTD was off the bottom. The echo sounder included a thermal-imaging printer, on which all of this was recorded, showing pulse times vertically on the page as the paper slowly advanced through the mechanism. The direct and reflected pulses from the CTD being lowered towards the bottom showed up as two sloped lines on the echosounder closing toward an intersection.

The typical procedure was to run the winch at full speed until the two lines on the echo sounder indicated a height above the bottom of 100 m or so. Then the winch operator was to be instructed to slow the winch for the final approach. The CTD was then stopped when it approached within 25 m or so of the bottom. The pattern that this would make on the echo sounder was a pair of lines progressing towards an intersection at a sharp angle, and then the lines became less steep as the winch was slowed until they nearly touched and the winch was stopped. Finally the lines would run parallel to each other until the first Nisken bottle sample was taken and the winch was reversed for its return trip.

After doing this several dozen times, the operation had become second nature. I even had come to know the response times of the various winch operators on the ship, with some being faster than others. I had the whole operation calibrated, as you might calibrate a video game that you had played dozens of times. And on this dark and stupid night I decided to see how good I was at this game. I decided to let the CTD go to the bottom at full speed. I watched as the lines on the echo sounder screamed towards each other at an obscene angle. Then just before disaster struck at the bottom, I yelled over the intercom to stop the winch. I had timed it perfectly and the two traces on the echo sounder were separated by the width of the trace lines. I suspect that the instrument kicked up a little mud when it halted. In any case, I popped the first bottle and instructed the winch operator to start bringing the instrument back to the surface.

Being very proud of my “accomplishment” I further compounded my folly by ripping off the paper from the echo sounder with my trace and posting it on the wall of the CTD lab. I added a note suggesting that the 4 to 8 shift was, shall we say, superior to the other shifts, challenging anyone to beat my trace. Stupid is as stupid does. The following two shifts
actually made some anemic attempts at this high-priced game of chicken. The game was finally put to an end when the chief scientist awoke from a long deserved sleep to discover the mischief I had started. I got the strongest possible reprimand from the chief scientist, and rightfully so. Now, looking back at my misadventure, I realize that if I were in his place I would have thrown me overboard. This was, after all, over $60K worth of instrumentation whose loss would have ended the experiment. Ah, the stupidity of youth. The moral here is to not try this at home, or anywhere else.

The Chain of Command

Another aspect of being professional is to respect the chain of command. When I ship out as a principal investigator (PI), but not as the chief scientist, I have to accept the role of the person who is the chief scientist. I have been out on cruises where the chief scientist is far younger and less experienced (but never prettier) than me. Still I know that I have to accept their decisions.

In these situations I argue my views strenuously, give the chief scientist the wisdom of my counsel, and try to help out as much as possible. None-the-less, when a decision is made, even when it goes against my interests, I have to abide by it. The only exception is on safety issues on which I will not bend.

Who’s Who in the Crew

When working on board a ship, you should know the duties and responsibilities of each crew member. While the exact organization varies from ship to ship, the following outline is typical.

Captain or Master - The captain’s foremost responsibility is for the lives and safety of all those on board his vessel. He is also responsible for the seaworthiness of his vessel and the protection of the interests of the operating institution. These are not responsibilities that are taken lightly. Failure to fulfill his duties can and often does result in a loss of the captain’s license, fines to the captain and his institution, as well as other penalties. Just remember that he is the boss, the head honcho, the big cheese, the top dog,... Well, you get the idea.

Deck Officers - The deck officers consist of the chief or first mate, followed in seniority by the second and third mates. The chief mate reports directly to the captain. The deck officers, who stand watches on the bridge, actually navigate and operate the ship. The acting deck officer must be notified before anything goes over the side of a ship or anyone goes aloft. Any course changes need to be coordinated with the deck officer. In case of difficulty, the deck officer is responsible for summoning the captain to the bridge.

Engineering Officers - The engineering officers consist of the chief engineer, who reports directly to the captain, and a group of engineering watch officers. The chief engineer is responsible for the operation of the ship’s engines and other machinery, ship’s maintenance, and the work of those in the engineering department. The engineering officers stand watches, just like the deck officers, maintaining and operating the ship’s equipment.

Other crew that report directly to the captain may include the radio operator (larger vessels only), the medical officer (also larger vessels only), and the steward. The steward is responsible for the operations of the galley crew, which may include the senior cook, the second cook and one or more messman. The steward is also responsible for providing bed linen and laundry and cleaning supplies.
The **Bos’n**, who reports to the deck officers, is directly in charge of the **seamen** who work on the deck crew. He is your main man when it comes to actually performing deck or over-the-side operations. When there are no deck operations, the seaman will be kept busy performing required work on the vessel, standing watches at the helm, and keeping lookout while underway. Some ships also have a **day man** who does not stand watch but keeps up with general ship maintenance with the assistance of the seaman.

The remainder of the crew in the engineering department consists of the **oilers and wipers** who work on the ship’s engines and machinery, the **deck engineer** who is responsible for the deck equipment, and the **electrician** who is responsible for the ship’s electrical systems. On many ships there is also an ET, or **electronics technician**, who is responsible for the maintenance of the ship’s electronics, including radars, navigation and computer systems.

This is quite a list, but keep in mind that while these positions are typical for larger vessels, responsibilities are combined as the crew shrinks. For example, on the *Minnow*, there was only the captain (The Skipper) and a chief mate (Gilligan). Of course I hope your cruises goes better than theirs did.

So with these responsibilities in mind, it is easy to determine who you need to talk to on any given problem. For example:

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<tr>
<td>Captain</td>
<td>any questions regarding safety, vessel scheduling questions</td>
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<td>Acting deck officer</td>
<td>maneuvering the vessel, putting an instrument over the side, climbing aloft</td>
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<tr>
<td>Electrician</td>
<td>finding additional power for a system</td>
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<tr>
<td>Deck officer and bos’n</td>
<td>planning a deployment operation</td>
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<tr>
<td>Steward or cook</td>
<td>obtaining clean bed linens</td>
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<td>Chief or deck engineer</td>
<td>a broken winch</td>
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Now that I’ve given you the official version of the ship’s hierarchy, let me finish this section with other versions, which though unofficial, are often closer to reality. Officially the hierarchy on board ship goes: captain, chief mate, chief engineer, deck officers, deck engineers, steward, bos’n, etc. As far as ship’s morale goes, the real hierarchy is much simpler: the cook, followed distantly by everyone else. For this reason, if none other, you should be nice to the cook. Of course you don’t want to get carried away with this as I once did.

I was performing an experiment in Norway, when a Norwegian submarine surfaced in the area. Informal arrangements had been made to provide the sub with newspapers and mail. I had always wanted to see a sub, so I begged a ride on the small boat that was sent over for a rendezvous. As we approached I yelled out an introduction to the young man standing on the deck. I told him I didn’t want to be a bother, but asked if I could get a short tour. He agreed and I climbed aboard. I asked if he wanted to check with the captain first, as he didn’t appear to be old enough to be more than a lowly lieutenant. He said that this wasn’t necessary and we proceeded down the hatch into the sub. He started the tour foreward, in the living quarters, where the bunks lined the narrow aisle from floor to ceiling. We proceeded aft stopping at the galley, which took up little more than a square meter of floor space in a small alcove. Upon my introduction to the cook, I jokingly commented, "I'm glad to meet the most
important man on the vessel!” The cook smiled, but the young officer muttered, “Well some people think so,” and proceeded down the corridor. Just aft of the conning tower there was a small room with but a single bunk. It was clearly the captain’s room as it was the only private space in the entire sub. The young officer just about floored me when he pointed into the room and said, “And this is my room.” I was so embarrassed. Yet again I had put my foot into my mouth — this time because I couldn’t read rank in the Norwegian navy and because I was trying to show off for the cook!

In some circumstances, the hierarchy of importance on a research vessel may shift to the following structure: bos’n, deck hands, deck officer, and everyone else. In particular, when you need to put something overboard into the water or recover something from the water, this is the hierarchy you need to be concerned with. Not that you should slight the deck officer, who is nominally in command of the operation, but typically the bos’n will be the person actually running the deployment or recovery.

This may sound more complicated than it is. If you just keep in mind that the responsibilities on the vessel are split, then you’ll do just fine. And when in doubt, just ask any crew member.

The Cruise Log

During the post-test analysis of data, questions will invariably arise about the interpretation of a particular piece of data. Those questions may pertain to the environmental conditions during a particular period, the state of the equipment, the distance between two sensors, the speed of a winch, or the manner in which a colleague acquired their data. It seems that no measurement is ever quite complete and so the interpretation of data always seems to hinge on these kinds of questions.

Providing answers to such questions that may arise long after the test is over is made complicated by the nature of at-sea work. The physical difficulty of the undertaking combines with the mundaneness of day-in, day-out operations to make it impossible to remember everything necessary to insure success in the post-test analysis.

The solution is simple: you should keep a detailed cruise log, recording everything possible about your instruments, the cruise and the environment that you are operating in. The key is to make this log as complete as possible. You will never have a problem from taking down to much information on a cruise, but the cost of missing some seemingly minor, and yet irretrievable, fact can be costly. Your log should provide an overview of the entire experiment, as well as your place in the experiment. It should include sufficient detail to describe the environment in which you operated. It should include all measurements, calibrations and observations that you make during the cruise.

I can usually tell how long someone has been doing field work by taking a look at the level of detail and completeness of their log books. When I first began going to sea my log entries were terse and incomplete. Now I try to write down everything. For example, I regularly include periodic meteorological descriptions including wind speed and direction, air temperature and humidity, and sea state estimates in my log. These provide some context for the measurements made during a particular period and the frequency of written notes provides an overview of how quickly conditions change. I write these things down even though more precise and regular measurements of these parameters, made by finely calibrated instruments, are being recorded onto digital media. I find the written overview a helpful adjunct to the subsequent environmental parameter plots that result from the data recordings. Furthermore, my written notes are the ultimate backup to catastrophic instrument failure. I have been on
Menard, in his book, had this to say about standing watch and keeping cruise logs:

Several new members of the scientific party had never been to sea before, and we began instruction on how to stand a scientific watch. In general this involves learning how to use and not misuse a variety of instruments, how to communicate with the ship’s officers on the bridge, and to sense difficulties in time to prevent them from developing. One must learn the speeds and operating conditions to pay out instruments behind the ship and haul them in. Most important, the watch stander has to keep accurate, detailed, legible records of what is happening: the depth, the intensity of the magnetic field, the water temperature, position of the ship, direction and speed of travel, wind speed and direction, and so on. Not all of these are necessary on every cruise, but they are typical of the diverse responsibilities of a scientific watch stander.

Elsewhere Menard relates that their cruise log accumulated an average of one line of notes per minute of operation for the entire duration of a four-month cruise!

The details of log keeping are a matter of personal taste. When I am not acting as chief scientist I will keep a single personal cruise log containing my summary of the cruise and my instrumentation systems. I’ll also try to record as much information as possible about my colleague’s systems. On more than one occasion I have ended up with the only record of some fact important to a colleague’s success. In these cases the small effort in writing down the data is richly rewarded by the goodwill generated from helping a colleague.

On those cruises where I am chief scientist and I also have responsibility for one or more instruments, I usually maintain two log books: one cruise log on the bridge and one instrument log back in the lab. The cruise log is shared with those other scientists that take over my responsibilities when I am off the bridge. In either case, I use a bound, ruled notebook for keeping the log. In this way I insure that the log is kept together and no pages are lost. I also maintain a separate set of three ring binders for keeping all of the on-board data analyses that are produced during the cruise.

Using pen and paper may sound a bit old fashioned in this day of the notebook computer, but I find it easier to initially record my logs onto paper. Computers are superior for recording straight text, but recording sketches, schematics and other graphic elements is far easier on paper. It is also easier to perform complex formatting of your notes, including the creation of tables, on paper than it is on a computer.

In this case, though, I am not being a modern day Luddite. Partially in recognition of the superiority of computer distribution of data, including cruise logs, I try to make the effort to transfer my log notes to the computer on a daily basis. While this takes extra time, it does allow me to review my notes with care and to fill in any gaps in the narrative while the day’s events are still fresh in my mind. Finally, my handwriting is so bad that if I didn’t transfer my logs to the computer, then no one could read them, including myself! This practice also gives me a huge advantage at the end of the cruise when it comes time to produce a ship cruise report. If I have managed to keep up with my transcription to the computer, the cruise report is essentially done when I walk off the ship.
Keeping to Schedule

When at sea you should constantly maintain a mental image of what tasks are underway at any given time, what tasks are upcoming and what tasks you need to perform. You must always remain aware of the cruise schedule to insure the timeliness of your actions. Cruises are rarely regular in their patterns of data taking opportunities. The diversity of instruments used on a typical cruise leads to sporadic data opportunities for most instrument systems, and when your instrument’s time comes, you need to be ready. In many cases, if you are not ready, someone else will be given the opportunity to use the time to take data. There is no excuse for missing data opportunities at sea because of a lack of preparedness.

Communications with the chief scientist is critical in keeping up with the evolution of the cruise. While I recommend that the chief scientist constantly promulgate (there’s that word again!) status and planning information to the scientific party and crew, it is truly the responsibility of the individual scientist to know what is going on at all times. If the chief scientist is not forthcoming with status information, then seek them out to get the information you need to do your job. Don’t allow a chief scientist who is wrapped up in his or her own work to prevent you from getting the most out of your cruise.

You should always keep your instruments as prepared as possible. For example, if you are working with Niskan bottle sampling, you should prepare the system for use immediately after obtaining the samples from the previous cast. In this way you will have maximized the time available to fix any problem that you may discover during the instrument preparation. This will also help insure the readiness of your instrument should a sudden, and possibly rare, data opportunity occur. Simply put, don’t put things off on a cruise.

Finally, on many cruises you will be working in shifts with other scientists. A typical cruise schedule might be 12 hours on and 12 hours off. I have also been on cruises where there were three watches, each working 4 hours on and 8 hours off. At the end of your shift you will find it incredibly annoying when your replacement is late. The point is that others will feel the same when you are late, so be on time. While regularly being five minutes late may be thought of as a minor idiosyncrasy on land, that same behavior on board a several week cruise will be treated by your colleagues as a serious offense. In fact, you should arrive a few minutes early for each shift to provide some time for the person you are relieving to communicate to you the current status and any special instructions necessary to perform your watch duties.

Know Your Limits

Situations will occasionally arise at sea that will require long hours of work to correct. Critical equipment might break, software programs may fail, or environmental changes may occur that require re-planning of the cruise. Your job during these times of crisis will be to do whatever is necessary to correct the problem (at least without sacrificing safety). Given the expense and scarcity of at-sea data opportunities, times will arise when you’ll be tempted to work beyond your limits. You’ll try to go without sleep to get enough hours in the day to solve your problem. I won’t tell you not to pull an all nighter to fix your problem, but it is important in these situations to know and to respect your own limits.

Humans require a certain amount of sleep in order to function and survive. People’s average daily requirements vary widely and depend on a number of variables including physical and mental stress. Sleep deprivation can be a wonderful and weird experience on land, but you shouldn’t try it at sea. As you become more tired, your response times increase, your mental acuity decreases and you start making more mistakes. I have found that it is time
to sleep when I begin to make mistakes or have difficulty thinking. When time is critical, even a few hours can act to revitalize your senses and actually speed the process of fixing the problem.

You’ll have to use your own judgment in each situation. I caution though that many people misgauge how tired they are. Don’t let sleep deprivation get the best of you.

**Decision Making**

Decision making goes to the heart of what it takes to be a successful at sea oceanographer. As you might expect, I suggest that if you are at all uncertain about a decision, no matter how minor, that you gather the views of others to guide you. You should be decisive but not rash. You should shoulder the responsibility for your decisions. And you should try to be as imaginative as possible, while all the while keeping the big picture in mind. Decisions made on the basis of a confined, localized view of the problem are often wrong. I’ll discuss each of these points in turn.

**Gathering Opinions**

I always try to get the opinions of others prior to making decisions. My colleagues will often see points that I have overlooked or weigh the various pros and cons differently than I would. The simple act of gathering the opinions of others also helps build a team mentality. After gathering opinions, though, the decision is still mine to make. I am not a big fan of committees, and while I do prefer to build a consensus on decisions that affect others, in the end a single person should take the responsibility for each and every decision made. I think shared responsibility spreads the cost of bad decision making and therefore reduces the cost of mistakes to any individual. It is for this reason that I think there should be one and only one scientist absolutely in charge of, and responsible for, each instrument.

The only time that I will substitute one of my colleague’s judgement for my own, is when that colleague is more expert in a given area than I. Even then I will ultimately maintain the responsibility for those decisions. While I think everyone should be afraid of failure, no one should be afraid of blame. Fear of blame and recriminations keep people from working at their best.

**Assessing Blame when Things Go Wrong**

On some of my cruises, there has come to be a standing joke about assessing blame when things go wrong. Early in a cruise I’ll often tell the story of an engineer I knew who always managed to blame someone else whenever something went wrong. In fact, the first I would know that a problem would exist was this engineer barging in with a statement that, “I told so and so not to do that! It’s not my fault.” After relating this small story, I try to shock my assembled colleagues by explaining that I plan on taking my lead from this engineer. When a problem is discovered, I expect everyone to drop what they are doing and focus on assessing blame for the problem. Only after we assess blame, I explain, can we proceed to fix the problem. The outrageousness of this approach is so obvious that it is humorous. The standing joke is then that when a problem does occur I’ll tell everyone within earshot to drop everything until we can assess blame. In all honesty, I expect this kind of behavior from my small children, but not from people in a professional environment. By making a joke out of it, I let people know that I expect them to focus on solving problems, not pointing fingers.
There is a wonderful story illustrating that I am not the only person that thinks this way. Years ago, JHU/APL was running a spin test on a navigation satellite just prior to delivery of that satellite for launch. The satellite was suspended from the ceiling of a building at the lab, when a cable broke and the entire satellite crashed to the floor, sending small pieces flying in all directions. After the countless hours that had been put into building the satellite, everyone present was devastated. Evidently there was no small amount of finger pointing and arguments about who was to blame for the mishap. The director of the lab was notified and immediately rushed to the scene. When he heard the commotion about who was to blame, he commanded silence. He told everyone in the room that he wasn’t at all interested in who was responsible. His only interest was in fixing the damage and readying the satellite for flight. At that, he bent down and started picking up pieces off the floor. Everyone chipped in, the squabbling stopped, and the satellite was actually repaired and delivered for a successful launch and flight several weeks later. As I said, this is a wonderful story that has been told around our lab. The only problem with this story is that, as far as I can determine, it never really happened. Still, the story is so good I thought I’d share it with you anyway.

Be Decisive

After gathering information, as well as the views others, it will be time to make a decision. When working at sea it is important that you be decisive, but not rash. Few things will drive a crew and colleagues as crazy as indecisiveness. I recently heard a story about a chief scientist who had a difficult time deciding exactly where he wanted to take his CTD measurements. He had the ship drive around in circles for several hours while he laid out the CTD locations and times for the next day. This obvious waste of precious ship time angered everyone else on board.

Imaginative Solutions

In addition to being decisive you should be open to novel or innovative solutions to your problems. A little imagination goes a long way. For example, I was once involved with the deployment of a 12-m long spar buoy in a Scottish loch. The buoy had to be slowly towed 10 km down the loch and through a narrow channel to its final mooring site. After a several hour tow to the narrows, we found the wind had picked up, making the passage through the narrows at low speed somewhat dangerous for the buoy. The crew wanted to know what to do – the two options being offered were to risk towing the buoy through the narrows, or turning around and slowly towing back up the loch, hoping the weather would improve within a day or two. After two or three minutes of what passes in me as deep thought, I pointed to a small pier and a group of salmon pens on the nearby shore. I asked one of the crew if he knew the owner and he responded that he did. (In this rather pleasant way, Scotland is a very small place.) My solution was to send the crew member over to the shore with the offer of a bottle of whiskey in exchange for the right to tie up our spar to this gentleman’s salmon pens. It turned out that the fish farmer was more than happy to oblige for free. We were able to cruise back to the staging area at the other end of the loch with good speed, and returned the next day when the weather broke to take the spar through the narrows and to its mooring. In this case, the non-obvious alternative was the correct decision. When you are faced with difficult decisions I hope you’ll remember to use a little imagination.

The Big Picture

My final advice is to make your decisions based on the big picture. You should try to envision all of the consequences of a decision. This is easiest after you have had the experience of several experiments under your belt. I think this point is best illustrated by a
story I have pieced together from the accounts of some colleagues present at a joint U.S. /
Norwegian experiment.

As part of this experiment a large number of sensors were connected to a single data
acquisition system. This system had 128 identical inputs, all of which accepted the same
voltage range, and all of which were sampled at the same rate. The signals from the sensors
had thus all been adjusted to match the range expected by the data acquisition system. The
outputs of this system were recorded locally on a hard disk by the Norwegians and
telemetered back to shore for recording by the American group.

Several days of operations were conducted before enough data were analyzed to indicate
that a number of wiring errors had been made. Apparently the technicians that had connected
the sensors to the system had made some mistakes and so a number of the channels had been
connected to the wrong inputs. The result of this error was that the data files were organized
in a rather odd way. Upon discovery of this error, one of the young American engineers
argued strenuously that the Norwegians should go out to the remote data acquisition system
and correct the wiring. The Norwegians refused. After a couple of days of discussion on the
point, the engineer gave up trying to convince the Norwegians and proceeded to correct the
channel wiring errors in his recording software.

So the question is, who was right? After the wiring error was made and data were taken for
several days, would you have rewired the system, or would you have left it alone? It has been
my experience that your answer will depend on how much experience you have had. When
faced with a nearly identical problem early in my observational career, I chose to rewire the
sensors part way through the experiment. I clearly recall thinking at the time that this was
the correct thing to do. After all, I was acting to correct a deviation of the operation from
the plan.

It was only later, when I began analyzing the data, that I understood that I had made a
mistake. From the beginning of the analysis to the end, the change in the data file formats
haunted me. I was always going back and checking the details of the change. I was always
writing special code into my analysis programs to deal with the change. One set of routines
would process data prior to the change, another dealt with the data after the change. The
entire affair was a royal pain.

Now, years later, I know that the Norwegians were right and the young American
ingineer wrong. I am now analyzing some small portions of these data sets. I received some
data from the young American and already have wasted time because he provided me with a
pre-change data set but post-change documentation.

For the record, here are the rules I have learned for dealing with this type of situation. If
a mistake is made in the field that affects the quality of the data, then you must endeavor to
make whatever changes necessary to get the best quality data. If, on the other hand, a
mistake leads to changes in the data which do not affect quality, such as a restructuring of
the data files, then it is best to do nothing more than record the new structure in your cruise log.
Consistency is very important in the analysis of data. Any changes which affect the data in
some time varying way, such as file restructuring of half of the records or the application of
time varying calibrations, should be taken care of once at the very beginning of the analysis
phase. I typically will apply these changes once to the raw data files, producing a second set
of corrected data, which are then used as the basis for all subsequent data analysis. (I'll
emphasize here that you should never do anything to change the raw data files directly, you
may need them later. The output of your programs should be to new data files, or you should
only work on copies of the raw data.)
Communications

I talked at length about communications planning in an earlier chapter, but it is important to strive for clarity in your communications on board ship. Small misunderstandings can be magnified by the forced closeness of living and working on a ship.

My colleague Dave Porter tells a story of a cruise he went on a number of years ago. Evidently the crew was quite unfriendly from the beginning of this cruise. Concerned about morale, Dave asked what the problem was, only to hear a story about the scientists on the previous cruise. It seems the previous cruise was doing acoustic work, periodically setting off small 0.5 kg explosive devices, called SUS charges, as underwater sound sources. These devices are designed with two pins: if the nose pin is pulled the charge goes off at 60 m depth, but if the tail pin is pulled the charge goes off at 300 m depth. Evidently, one morning at 2 AM, whether by accident or on purpose no one was sure, a SUS charge was deployed that went off at 60 m. While the crew was accustomed to the mild thud of the deeper explosions, the near-surface explosion was much louder than normal and woke everyone on board the vessel. This alone would have been but a minor annoyance but for the communication breakdown that immediately followed.

The officer of the watch, hearing the explosion, telephoned to the science lab near the aft deck and inquired as to what had happened. He should have been told that the scientists didn’t know, but would check into the matter and report back immediately. Instead, the scientist who answered gave the rather short reply that it sounded like an explosion on the aft deck. With this information the officer of the watch had no choice but to sound general quarters, mustering all hands. Relations were never quite the same after that mistake, and the crew’s unhappiness even spilled over into Dave’s cruise. The moral of this story is to be certain of your facts and clear in your communications whenever possible.

Your Job At Sea

Soon after I began working at JHU/APL I was befriended by one of our most senior scientists. During one of our conversations I happened to ask him about my responsibilities at the lab. I was confused by the lack of support people around to help me with my work. I am not sure what I expected, but I found that I was having to do everything, including manual labor when I wanted something moved. So I asked him what my job description was at APL. His answer was simple, “You’re supposed to do whatever needs to be done.”

That conversation took place over 20 years ago, but to this day, when someone asks me what I do for a living, this is the phrase that pops into my mind. I’ll admit that I usually tell them I’m an oceanographer, but in reality I do whatever needs to be done. And as it is within our lab, so it is at sea. Your job at sea is to come back with the data, and you’ll be expected to do everything that is safe and prudent to achieve that goal.

You may have noticed that I didn’t limit the above statement to “your data”. Instead I said “the data”, meaning all of the data that is necessary to meet the scientific goals of the cruise. While your first responsibility is to your systems, after they are working, you should see if you can help out someone else. Even as chief scientist I like to help out with deployment operations, or chip in to help solve engineering or software problems where I can. Helping out others at sea is a good habit to develop. There are just two cautions. First, be sure that it does not distract from your own responsibilities. And two, don’t be a pest or get in the way. It is quite easy to get too many people involved with a deck operation or repair effort. My rule of thumb is to offer help once. If the answer is no, then I get out of the way.
and let the others do the work. On deck operations I prefer to be out of the way but nearby so that I can help if necessary.

**The At-Sea Classroom**

At some point in your career you may go to sea with students of your own or other professors. Students at sea are some of the most energetic and inexpensive workers available. (My colleague Dave Porter jokingly coined the acronym XGS, or expendable graduate student, to describe how students are sometimes used at sea.) While useful as slave labor, don’t forget though that they are in school to obtain an education and that it is everyone’s responsibility to see to their schooling. On a cruise of any substantial length it is worthwhile to try to organize educational activities for the students.

The first order of business should be training those new to life at sea in safety and ship etiquette. While much of this book is devoted to these topics, this training at sea will necessarily be an ongoing venture as there is a lot to learn. The second set of topics should be the operation and use of equipment, the techniques of standing watches, and the keeping of the cruise log. These topics represent the minimum knowledge necessary to operate at sea.

Unfortunately, too many scientists stop here, and proceed no further. Instead, I suggest that the entire cruise should be viewed as an at-sea classroom. Your top priority should be a set of seminars on the scientific issues associated with the measurements being made on the cruise. It would also be a good idea to have a willing member of the crew teach students basic seamanship, including navigation, knots, crane hand signals, and the like. Finally, I think it a good idea to try to teach students how to conduct an oceanographic experiment. Here are the words of Menard on the subject:

A few days earlier it had occurred to me that our teaching program on the expedition was flawed. We were teaching the students how to survey submarine topography, stand scientific watches, take cores and dredge, measure heat flow, and live on an oceanographic expedition. What we were not doing was teaching anybody how to manage expedition operations. In fact we had never taught anybody how to run an expedition since our general procedure was evolved in the early 1950s. Some people had a knack for it and ran expeditions and some didn’t. Usually a student was chief scientist only when he was lucky enough to be working with a small group of fellow students and friends on his own thesis problem. No one ever ran a ship with a teacher watching the operations. A “chief scientist of the day” was forthwith appointed for the next three days and three students were successively in charge of operations. It seemed to work very well.

...Each of the students made mistakes but they were of such a nature as to reveal that no other method of teaching would work.

When thinking about an at-sea training program, remember that hands-on experience offers unique opportunities for learning that cannot be duplicated on land. Even the most trivial events at sea offer the opportunity for learning. I recall an incident on the first cruise that I was ever on. We had just brought a rosette back on board from a cast to the bottom of the Caribbean. It was a warm, sunny day and I was out on the deck in shorts and flip-flops. (I know this wasn’t particularly bright, but I was new to working at sea.) A post-doc had been asked to show me how to take the water samples from the Nisken bottles and to prepare the rosette for its next cast. After taking the samples, we had to empty the remaining water and re-arm the bottles. The post-doc, smiling, instructed me to grab the bottom cover on bottle number one, the deepest sample, and pull to release the water. I did as instructed and several
liters of frigid bottom water poured onto the deck and my feet. I let out a scream and jumped several meters. “Damn that’s cold,” I shouted. The post-doc laughed, and put his arm around my shoulder. “What year of graduate school are you in?” he asked. “Second” I replied. “And how cold is the water at the bottom of the ocean,” he continued. “A few degrees,” was my response. “Well that is what a few degrees feels like,” he replied. While it is a trivial example, intellectually I knew how cold bottom water is, but I never really understood until that warm Caribbean day. Opportunities for this kind of learning abound. Whether you are the instructor or the student, don’t let them pass by.

**Seasickness**

Seasickness is one of those ugly things that will be hidden from you in graduate school. Many oceanographers get seasick. I, for one, get violently ill almost every time I go to sea. It was during my first cruise, in fact, that I came to understand why guns are not allowed on research vessels. We had only been out a few hours when I got sick. For the next few days I would beg everyone passing by my bunk to give me a gun so that I could put myself out my misery. Seasickness is no fun.

There are at least two ways to avoid seasickness. The first is to choose your chromosomes wisely. Some people never get sick. If this is not an option for you, then I suggest that you take drugs. I favor Transderm Scop, a behind the ear scopolamine patch that works wonders on me.

Still, there are a variety of other choices. While I am not a medical doctor, and I don’t play one on TV, I have prepared a list of available motion sickness drugs for your perusal. I caution that I am not recommending any of these drugs. The list is provided for your guidance only, and I strongly recommend that you see your physician before taking any medication. Just three of these medications are available over-the-counter: Dramamine, Marazine, and Benadryl.

There are several important points to note regarding these drugs:

- Note that virtually all of these drugs list drowsiness as an adverse side effect. Individual reactions can vary widely, so I suggest you try a new drug on shore, before going to sea, to determine how your system will react.

- The list distinguishes between drugs that act to prevent nausea and those that treat nausea. Those that prevent nausea must be taken prior to going to sea. Such drugs will not aid you once you are afflicted.

If you do happen to get sick at sea, then you’ll want to lie down, preferably in a cool, dark place. Try to keep eating, even if it is small amounts. Unsalted crackers are a good choice. Also, try to get up and test your sea legs. When you get ill again, go back to bed – but keep getting up and you’ll recover faster. The good news is that most people get over their seasickness in a few days. The bad news is that some people never get over it. For those people, I recommend a career in numerical or theoretical oceanography.

Seasickness is incredibly uncomfortable. It is extremely bad form to make fun of someone who is sick. Remember that the person you make fun of today will likely feel better tomorrow. The last person who did this to me had a long time to think about the error of their ways during their long swim home.
<table>
<thead>
<tr>
<th>Motion Sickness Drugs</th>
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<tr>
<td><strong>Buclizine Hydrochloride (Bucladin)</strong></td>
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| 50 mg tablets  
Acts centrally to suppress nausea, vomiting, and dizziness associated with motion sickness.  
Contraindicated for use in early pregnancy.  
Adverse reactions: occasionally drowsiness, dryness of mouth, headache, jitters.  
Adult dosage: One tablet 1/2 hour before trip. One tablet twice per day. |
| **Cyclizine Hydrochloride (Marezin)** |
| 50 mg tablets, available without prescription  
Antiemetic acts to suppress nausea, vomiting, and dizziness associated with motion sickness.  
Contraindicated for use by those with asthma, glaucoma, emphysema or chronic pulmonary disease.  
Adverse reactions: drowsiness.  
Adult dosage: One tablet 1/2 hour before trip. One tablet every 6 hours. |
| **Dexchlorpheniramine Maleate (Polaramine)** |
| 2, 4 or 6 mg tablets  
Antihistamine with unlabeled use in the treatment of nausea and vomiting due to motion sickness. Dosage should be adjusted to patient, but do not overdose.  
Contraindicated in those sensitive to antihistamines, those taking monoamine oxidase inhibitors or oral anticoagulants. Don't use in conjunction with alcohol.  
Adverse reactions: slight to moderate drowsiness, as well as a range of less likely reactions to antihistamines.  
Adult dosage: One tablet every 4 to 6 hours. |
| **Dimenhydrinate (Dimetabs, Dramamine)** |
| Available without prescription  
Acts to prevent and treat the nausea and vertigo associated with motion sickness.  
Adverse reactions: drowsiness  
Adult dosage: 50 mg every 4 hours, 100 mg every 4 hours if drowsiness is acceptable, not more than 400 mg per day. |
| **Dimenhydrinate Hydrochloride (Benadryl)** |
| 25 mg tablets, available without prescription  
Antihistamine for prevention and treatment of motion sickness.  
Contraindicated in newborns, nursing mothers, those with sensitivity to antihistamines or narrow-angle glaucoma, or those taking monoamine oxidase inhibitors.  
Adverse reactions: drowsiness, dizziness  
Adult dosage: 25 mg, 3 to 4 times daily, 50 mg sleep dosage. |
| **Meclizine Hydrochloride (Antivert)** |
| Antihistamine which does better job of preventing, than treating, motion sickness.  
Contraindicated in those with sensitivity to antihistamines. Don't use in conjunction with alcohol.  
Adverse reactions: possible drowsiness, dry mouth  
Adult dosage: 25 to 50 mg one hour before trip, same dose once daily. |
| **Promethazine Hydrochloride (Phenergan)** |
| Suppositories, Tablets, Syrup  
Antihistamine which relieves effects of motion sickness  
Adverse reactions: drowsiness, dry mouth  
Adult dosage: 25 mg 1/2 hour before trip, same dose twice daily with meals. |
| **Pyridostigmine Bromide (Mestinon)** |
| 60 mg tablet, 60 mg syrup, 180 mg slow-release tablet  
Unlabeled use to control effects of motion sickness.  
Contraindicated in patients with urinary or intestinal obstructions or bronchial asthma.  
Adult dosage: Must be individually set. |
Transdermal Scopolamine
0.5 mg/day for 3 days from behind ear patch
Prevents, but does not treat, nausea from motion sickness, significantly more effective than Dramamine
Contraindicated for those with glaucoma.
Adverse reactions: dry mouth, drowsiness, disorientation
Adult dosage: Apply one patch behind ear at least 4 hours prior to trip. Change patch every three days.
Discard old patches and thoroughly wash hands after handling patches. Avoid contact of Scopolamine with the eye.

Offload

So you’re at sea but heading home after a long and successful trip. It would be nice to kick back and relax at this point, but one of the worst jobs is just beginning, the offload. After every cruise that I have ever been on, the participants are anxious to get done and to get home to their families and their nice stable beds. For this reason, the offload of the equipment is too often a hurried mess. Things get thrown into boxes helter skelter with the idea that it will all be sorted out back at the lab. This inevitably leads to a mess that must be dealt with back home.

There is a better way. Just come prepared for the offload and take your time in packing your equipment and left over supplies, so that they don’t have to be unpacked at the lab just to be put back into storage. A bit of care and organization up front takes little extra time, but can save you hours of work down the road.

First, you should go prepared to pack as much as you can on ship. Much of our instrumentation is turned off on the return cruise so packing can be conveniently done on ship. This requires that you take along boxes and shipping crates for the equipment. These can often be carried in holds below deck. You should check with the captain and crew about this possibility well before sailing.

The next task should be to use fresh water to clean off any oceanographic equipment that has been deployed, and any other equipment that has been exposed to the weather. After cleaning, the equipment should be dried and then boxed. This will not only reduce the effects of salt corrosion but will also go a long way towards eliminating that low-tide smell that can end up permeating your lab back home.

Even without boxes and crates, there is a lot you can do to speed up the packing once you get back into port. Remove and neatly coil cable that has been strung about the ship. Neat coils are a lot easier to handle and pack than a tangle of knots. Another trick is to use large zip lock bags to keep small pieces together with the system to which they belong. For example, when we dismantle a buoy, all of the hardware removed from that buoy goes into a set of zip lock bags that are then kept with the major buoy components. Likewise I bag all cables, along with the mouse, that go with a particular computer. This allows me to easily reassemble that computer system when we get back to the lab. It also helps to cut down on the hours spent looking for missing components.

If boxes are available, then they should be filled and kept on deck. Boxes kept on deck are subject to salt spray and weathering, so I usually will try to keep any filled boxes covered with a thick plastic tarp that is securely fastened. This is a good precaution even of the shipping boxes are supposed to be waterproof.
Last, but not least, data should be packed in separate labeled boxes. I like to ship one set back to the lab, while I hand carry the backup set. This provides protection for the data in the unlikely event of a shipping accident.

The bottom line is to plan ahead. You know that you’ll have to get your equipment back to your home institution after the cruise, so there is no excuse for not being prepared. Try to be neat and methodical in your packing. And be doubly careful about transporting your data home.

Nautical Terminology

You’ll often hear doctors use odd words like “thrombosis”. Likewise, lawyers use words like “discovery” in ways that differ from the rest of the human race. Such unique vocabularies have developed to describe technical terms that are not in common use, and to elevate the users into a separate clique away from the rest of society. Sailors are no different, having created a rich and unusual vocabulary over the last thousand years, give or take a week. A glossary of nautical terms appears in Appendix B. A few hours of study, combined with a few years of hanging around the docks, should get you to the point where you can talk like a sailor. I don’t know whether you’re mother will approve, but when at sea, you’ll fit in better. There are a few terms though that are especially important, which I will discuss here.

Never call a sea-going vessel a boat. Always use the term ship. If you forget this simple rule and call your vessel a boat, someone from the crew will invariably tell you that a boat is something that can be lifted onto a ship. While you are on the ship though you are likely to hear the crew refer to the vessel as a boat. Resist the urge to correct them as the crew may later have total control of a crane that is holding the instrument on which your scientific career rests. My best guess is that this is a grand conspiracy by the crews of oceanographic vessels all over the world to confuse scientists. And my advice is to just play along.

Learn the terms port (left) and starboard (right) so that you know them backwards and forwards. If you are not 100% certain of the terminology, just use left and right. Only the ship/boat thing will rile a sailor up more than someone confusing port and starboard.

If you are dealing with any instrumentation that measures currents or winds, then you absolutely, positively must know the difference between heading and course. Heading is the direction the ship is pointing. Course is the direction that the ship is traveling. These need not be the same. For example, when a ship is drifting, it drifts in the same direction as the wind (assuming no current), but it usually aligns itself broadside to the wind. Thus the course would be in the wind direction but the heading would differ by 90°. The difference between course and heading, which is referred to as the crab angle, generally grows as a vessel slows down.

Knots

While being an oceanographer should not be confused with being a Boy Scout, the two share a common requirement of a simple knowledge of a few knots. You needn’t worry about becoming a professional rigger, but taking the time to learn a few knots will pay off during your career. I have included a set of diagrams for some of the most useful knots in Appendix D. I urge you to study and practice them. Of course, you are probably busy and feel you don’t have time to learn a bunch of knots. Well, if this is the case, then you should at least learn the single most useful all-purpose knot, the bowline. It is a strong knot that can be used for
just about any purpose. When in doubt I tie a bowline. It is also a versatile knot – in a slightly different form it is called the sheet bend, which is used for joining two lines together.

Test Conduct Checklist

- Always act professionally, safety comes first, then the job
- Respect the chain of command
- Maintain a detailed cruise log
- Keep to schedule on all tasks
- Keep communicating with the other scientists
- Respect your limits, don’t overwork
- When making decisions, gather opinions, use your imagination, maintain the big picture, weigh options, and be decisive. If mistakes are made, assume responsibility.
- Share responsibility for educating graduate students
- Help others when you can, but finish your work first
- Prepare for offload
Chapter 5. Instrumentation

Development

While most oceanographers will use instruments and buoys developed by others, there is a large number of people who will have the opportunity to design, build, and field their own instruments at some point during their career. Thus, I begin this chapter with a few pointers on the development of instruments and buoys.

This subject may strike you as strange, given that this book is about the conduct of oceanographic experiments. Actually, the lessons to be learned from instrument development can and should be applied to the use of off-the-shelf instruments.

Within this chapter, I’ll distinguish between instruments, which are primarily sensors developed in the lab to measure some properties of the ocean, and buoys which are platforms on which instruments are mounted. I am a near-surface oceanographer so I have a bias towards buoys, but moorings of all types would also fall into the category of instrumentation platforms.

Instrument development is a complex undertaking involving a wide range of interdisciplinary knowledge. You typically have to know enough oceanography to understand the properties that you want to measure, enough physics to understand the actions of the sensor that you’ll use to make that measurement, enough electronics to create circuitry to support that sensor, and enough mechanical engineering to package the instrument. Add to this the knowledge of software and computers required to acquire the data from the instrument and you have a formidable undertaking. So much so that I know of few people with the necessary broad skills required to develop a new instrument entirely on their own. Instrument development is typically a team endeavor.

Instrument Design

I have a number of ideas for new instruments bouncing around in my head, but funding for new instrument development is difficult to find. I have been involved, though, in the design of one new instrument, a capacitive wave gauge. Now I don’t think I’ll win the Nobel prize for my contribution to this endeavor, but a cursory examination of the design elements might be useful.

The sensor for the APL wave gauge system is an anodized tantalum wire. While tantalum is a metal, and hence a good conductor, the anodization process forms a very thin layer of tantalum oxide about the wire’s exterior. Tantalum oxide is a good insulator and dielectric, so the sensor works by measuring the capacitance between the metal interior of the wire and the surrounding sea water.

The original idea for a tantalum sensor was developed by Blythe Hughes and Ron Chappell of the Defence Research Establishment in Vancouver, British Columbia. Their original system utilized a sea water anodization process which resulted in a rather irregular and brittle oxide coating. An engineer at APL, Chris Keller, further developed the system by switching to anodizing in a weak acid solution. This made for more uniform coatings. Keller also modified a circuit originally used by the Canadians to convert the capacitance of the improved sensor into a voltage that could be fed into a data acquisition system.
After Keller’s retirement in 1990, I took up the development system and together with my colleagues Frank Monaldo and Jim Allison performed an extensive series of experiments to quantify and understand the anodization process. We uncovered undesirable artifacts in the sensor response and developed methods to minimize those artifacts.

At the same time, I began the design of a new, lower power version of the wave gauge electronics board. I came up with a brand new design that promised lower cost, lower noise and lower power operation. I breadboarded a simplified version of the design and verified its operation. I then gave the full design to one our electronic engineers, Robert Miller. Bob spent a few minutes looking at the design and then proceeded to lecture me for 15 minutes on all of the design mistakes that I had made. The op amps weren’t bypassed properly and would likely oscillate, the oscillator was only marginally stable and would likely have startup problems, the dependency on power and temperature fluctuations were not what they could be, and the circuit would fail catastrophically if the sensor was momentarily shorted. Instead of being angry, this just reinforced my view that Bob was the right guy to finish the design. He cleaned up the design, had some printed circuit boards made, and tested the final assembly. The system ended up cheap, precise, and rugged; a tough combination to beat.

(As an aside to this story, I’ll point out that I actually have a Master's Degree in Electrical Engineering from a name-brand university, while Bob does not. This just goes to show that a piece of paper hanging on the wall signifies little!)

A similar story can be told about the mechanical design, where I came up with an initial concept, showed it to a mechanical engineer who then improved upon it. The moral here is that no one person can do these things alone. If you are going to design an instrument, be sure to use some experts along the way, if for no other reason then to validate your design. Working with others will make it no less your instrument, because instrument development always requires someone to see the system through to the end. But working with others will significantly increase your chances of success.

The final act of developing the new wave gauge system was to test the entire system. In these tests, we built several copies of the system and tested the design’s tolerance to expected component variations. We measured the power consumption of the units as a function of voltage. I tested the stability of the unit as a function of voltage, both in the middle and the extremes of its ranges. I cranked the voltage up on one unit until it failed, measuring its failure point, and its failure mechanism. This let me know which parts to provide spares for in the field. I tested the unit stability versus temperature and water salinity. We checked the linearity of dozens of sensors and tested the sensors and electronics for short and long-term drift. In short, I did everything I know of to calibrate and test the system and all of its components. I documented all of these tests so that now we have a relatively good understanding of the system as a whole. And this was all done for a simple wave gauge!

Buoy development is in many ways similar to the development of an instrument. Here the stress is placed on the system, both the mechanical aspects of holding the instruments, but also the electrical and electronic aspects of power distribution, data multiplexing, storage and transmission and instrument control. The system is the key, and how well the parts merge to form the system will determine the success or failure of the buoy.

I can’t provide you with a complete set of guidelines for designing buoy systems. That would take a longer book than this and more expertise than I possess. I can tell you though that the same advice that I gave above for instruments, also applies here. Get experts in the various fields involved early in the design. Test, calibrate and characterize every aspect of the system that you can get your hands on. Finally, you should design for every eventuality,
anticipate failure modes and build in protection against them. To illustrate these latter points, I’ll provide an example of how not to build a buoy system.

*How NOT to Build a Buoy*

On a recent cruise, a new buoy was deployed for the first time by a colleague who had never designed a buoy before. When I first saw the buoy I knew we were in for trouble. The buoy was a free-floating surface-riding device whose primary sensor was an optical device. As anyone who has ever worked in an optical laboratory knows, all optical devices are painted flat black to cut down on stray reflections. Well the designer had really taken this convention to heart. His entire buoy was painted flat black! To make matters worse, the buoy was only about 2 m high with less than 1 m above the water line. I pointed out to the designer that we would be deploying this buoy near or possibly inside the Gulf Stream and that it would be difficult to find if it got away from us. He assured me that this was not going to be a problem because it was quite easy to see.

On the first day of deployment of the new buoy, things went from bad to worse. The buoy was rigged and lowered in to the calm waters of the Atlantic. Its gross ballasting appealed to be fine, so the designer gave the signal to move the ship away from the buoy. We had not traveled 50 m away when the buoy keeled over and layed down on its side. We circled back, hooked onto the buoy, pulled it upright and then again released it. Again the buoy fell over. The designer came to the amazing conclusion that the boat must be sucking the buoy over, so he instructed the skipper to try again but this time with minimum use of thrust. This time the buoy stayed up for a couple of minutes, but again it fell over.

It was clear to all of the rest of us on board that the buoy just wasn’t stable. I asked the designer who had decided upon the distribution of buoyancy and weight. He replied that he had. I then asked about the results of the stability calculations for the buoy. He didn’t quite understand the question, replying that it floated fine in a lake. It was at this point that I understood that he had done no stability calculations. Appalled, I walked away.

After several days of screwing around with the buoy, I finally convinced the designer to add some extra weight to the bottom of the structure. I wanted to add the weight on a line, so that the righting force would be maintained even if the buoy started to lie over, but he felt no need to do that and just attached it to the bottom of the buoy structure. This time the buoy rode a bit lower in the water when it was deployed, but it seemed to stay upright as we sailed away to deploy additional instruments.

Several hours later someone came in to the lab to inform me that the buoy had been lost. Apparently the designer of the buoy left the bridge for some time to attend to some data analysis and so had lost the buoy both visually and on radar. We knew where we had dropped the buoy off, so I asked to see the notes on the track that the buoy had taken while it was in the water. The designer had recorded its distance from the ship as a function of time while he had tracked it, but not its direction! Thus we had no track to project for the search. Still, we recovered our other instruments and proceeded to search for the lost buoy. We were joined in our search by another research vessel and a P3 aircraft that were also participating in our test. The costs of the search were quite high, but we felt that we had no choice.

A couple of hours into the search I innocently, and in all seriousness, commented that it would be dark soon making the buoy easier to find. The designer was surprised and asked me why I would think such a thing. I uneasily explained that when it got dark, the beacon light would come on and be easily seen at considerable distance. He then asked, What beacon light?
I was stunned. Here is a guy that built a small buoy, painted it flat black and deployed it near the Gulf Stream edge with no beacon light and no Argos transmitter!

In what must have been the act of a kind and benevolent supreme being, the P3 finally located the buoy. It was lying on its side several kilometers from our location. When we recovered the buoy I examined it. At this point I was not at all surprised to find that the designer had not even written his or his institution’s name and address on the buoy.

We finished the cruise without further incident. In retrospect I’m the first to admit that the designer of this buoy is a bright guy. I am certain that he learned a lot of lessons for his next cruise. Still, his mistakes should have been avoided by consulting with any number of people who have experience in buoy design. The sheer number of mistakes that he made with this single system was astounding. It was clear that he did not understand the environment that the buoy would be operating in, and that he had not given any thought to the recovery of his system.

Design Rules

The best path to good system design is to believe in Murphy’s Law: If anything can go wrong, it will. As I will say time and time again in this book, you should expect things to fail when you go to sea. The trick is to design a system that can continue to work if something fails. To understand the philosophy you need to understand the concept of point failures. Let me illustrate with the simple example of power distribution on the APL wave spar buoy.

The power distribution system in the APL wave spar buoy begins with a single set of 12-volt batteries, wired in parallel. The power from these batteries is then fed through a remote control system to each of the individual instruments. The remote control system allows each instrument to be turned on or off individually.

![Diagram of power distribution system](image)

Beginning with this simple conceptual design we then considered different failures that could occur and how each would affect the operation of the system as a whole. For example, suppose one of the instruments flooded and shorted out. While the remote control system was designed to turn off individual instruments, the batteries could be drained if we didn’t notice the problem right away. Thus we put fuses in line with each individual instrument. We reasoned that if the fuse blew, we’d lose the use of the instrument but save the system.
So far, the system is still quite simple. Next, we considered the effect of a failure in the remote control system. That system could fail with the power left on or off or in some undetermined state. We decided to run the power for each instrument through a set of toggle switches which allow us to manually turn the instrument on, off or set to remote control. These switches were mounted on the outside of the telemetry and control box, where they can be reached from a small boat in an emergency.

Then we considered what would happen if the main power line from the batteries was shorted accidentally during work on the system. Our concern that we could burn out a cable or connector led us to add a fuse to the main power line. This fuse was made larger than any of the fuses for the individual instruments so that it would blow last. It is important to realize that this fuse is a new single point failure mode for the system – if it fails, the entire system fails. In this case we made the conscious decision that if this failure mode occurs, the system is in deep, deep trouble and in need of serious repair.

Next, we worried about the possibility of the batteries, which are 10 m underwater in our design, running out of power before the end of an experiment. Thus we added a second power cable running up to the surface from the batteries to allow for charging of the batteries while the buoy is deployed. This has, in fact, been done using an umbilical cable from a nearby R/V. The charging cable was routed directly to the batteries, instead of through the control box, to prevent the voltage drop across the extra 10 m of cable from raising the voltage at the control box to dangerous levels. Finally, we added voltage monitoring circuitry and firmware to the control system to monitor the battery state.
In this real-life design case, we first developed a simple conceptual model that provided the functionality that we needed. Then we spent considerable effort analyzing this simple design to uncover what could fail in the design and how each failure would affect the system, giving the highest priority to single point failures that could disable the whole system. We then iteratively modified the design to anticipate and abate the worst failures. This is the only approach to design that I know of in the face of Murphy’s Law.

**Preparation**

I cannot tell you how many times that I have heard people discuss problems that they had at sea because they had not checked out their system before sailing. Preparation for a sea cruise is hectic and invariably undertaken without sufficient time to check everything out. Time and time again I have seen systems wired together for the first time the day before we set sail and software being written on the transit out to the experiment site. Sometimes, due to delivery schedules of components, this is unavoidable, but in other cases it is a sign of unprofessional preparation. It should always be the course of last resort.

Let me give an example. On my first cruise I was the lowest form of life at sea: a graduate student. I was on a ship from a well-known institution simply for the at-sea experience. I had finagled my way onto the cruise because I figured that I should go to sea at least once if I was going to call myself an oceanographer. Doron Nof, a well-known theoretician who was my major professor, disagreed. His initial view was that there was nothing in oceanography that couldn’t be learned from behind his desk. Naturally, I am exaggerating here, but I wanted to try a cruise just once and I talked him into supporting my adventure.

Once on the ship, I was determined to make myself useful and to learn something. I attached myself to the chief engineer in the scientific party, offering to help in his work of setting up and checking out the equipment. For his part I think he accepted my invitation so that he’d have someone to fetch him coffee. To me it seemed a fair bargain.

On our second day at sea, the engineer asked me to help him change over the CTD to a new winch with brand new cable. The old cable had been in service for several years and was at the end of its safe operating life. The new cable had been ordered from the same manufacturer that had made the original. Unfortunately it was delivered late to the ship so that the engineer only had time to spool it onto the backup winch prior to our setting sail. To switch to the new system we had to terminate the new cable, check the entire system out
electrically and then jury rig a new slip ring assembly onto the backup winch. The slip ring assembly went together easily as the engineer had thought ahead and brought sufficient parts to do the job. The cable termination appeared to go well. The termination involved pouring molten lead into a mold to provide a strong mechanical connection. The trick in the process was to avoid damaging the insulation of the internal electrical conductors when the molten lead was poured.

When the termination was complete, we hooked up the deck box, which controlled the Nisken bottle releases, to the slip ring assembly and the release to the newly terminated end. The system didn’t work. The engineer patiently explained that sometimes, as careful as you may be, the internal wires get damaged by the termination process. He cut off the termination with a hacksaw, and spent another half hour re-terminating the cable. Again the system didn’t work. This time we decided to check out the cable for continuity and short circuits. It checked out fine. We then hooked up the deck box and release, and examined the signals at both ends of the wire. The signal at the release end was very weak, despite the good continuity check. By this time there was a lot of cussing and scratching of heads to try to figure out what was going on.

I got the engineer to explain to me how the deck box system worked. The system utilized audio tones, like in a computer modem, to control the instruments. The deck box basically generated these tones under user control and sent them down the line using an AC current source. I suggested that maybe the electrical capacitance of the cable was too high for the deck box to drive the signal down the line. The engineer explained to me in patient tones that the cable was made to a particular capacitance specification and so this could not be the problem. He added that we didn’t have a capacitance meter on board so we couldn’t check the system even if we wanted. Despite his certainty that the problem lay elsewhere, he was in the end unable to figure out how to proceed, so he let me work on the system.

I computed the total expected capacitance of the cable from its specifications. I then got a comparable size capacitor from the ship’s stores and a variety of resistors to create a long time constant. I hooked up a resistor in series with the capacitor and measured its resistance using an analog multimeter. As the capacitor charged up in the circuit, the multimeter swung from a low resistance reading to infinity. I changed resistors until the time constant of the needle swing could be easily measured. I associated this time constant with the particular capacitance I had selected. When we hooked the same resistor in series with the cable and placed the multimeter on it, the needle swung much more slowly to infinite resistance. By adjusting resistors to arrive at the same time constant as in the test case I was able to show that the capacitance of the cable was about three times the specification.

At this point we had figured out what the problem was. The solution then followed. At my suggestion the engineer got out the schematics for the deck boxes. The decision was made to parallel the output stages of two deck boxes to double the total drive current. When he hooked up this kludge of a system to the slip ring assembly everything worked fine. The cruise proceeded from that point with out major incident.

If we had not been able to diagnose and fix the problem with the cable, we would have had to scrub the entire multi-million dollar experiment, or taken a major risk in losing $100K worth of CTD by switching back to the old, worn cable. While it would have been easy to diagnose and fix this problem on shore, we barely managed to avoid these rather dire consequences at sea. Most times things won’t work out this well, so it pays to fully check out your instruments prior to sailing.

In a less dramatic example, I once took delivery of some current meter mooring frames on the dock just before I was to set sail on a Russian research vessel. The current meters are
supposed to bolt into these frames, which then hold the current meters securely on the mooring. On our second day at sea I was preparing the moorings for deployment when I realized that not only did the frames not come with any bolts, but that I had failed to bring along any bolts of sufficient length to mount the current meters into the frames. After much cussing I asked my Russian colleagues if they had any long bolts. When they told me no, I cussed for a while longer than sat down on the deck staring blankly at the useless frames. Naturally I felt like an idiot.

Fortunately for my reputation, this story too had a happy ending. One of the Russian technicians noticed my predicament, motioned for me to wait, and headed off to the machine shop. Not being known for my ability to follow instructions, I picked myself up off the deck and followed him to see what he was going to do. In the ship’s small machine shop, he got some hexagonal stock, put it on a lathe, and proceeded to make the necessary bolts. I, like most scientists that I know, thought that bolts came from a hardware store. I never realized that they could be made by real people! The technician’s ingenuity saved the day and we deployed the moorings on time. After deployment, I went into our lab, fired up my computer, and added several pieces of assorted threaded rod and nuts to my list of parts and material to take on each experiment. I am determined not to make the same mistake again.

My primary lesson from this was to assemble and check out everything possible before going to sea. When I am going to deploy an instrument (or buoy or mooring), I first completely assemble the instrument in the lab. Then I check out its operation. Finally I take the system apart for shipment, being careful to bag and mark all of the nuts and bolts, cables, and odds and ends necessary to make the system work. This doesn’t insure that you will have remembered everything, but it does seem to help.

One case where this procedure didn’t quite work out occurred on an experiment in 1989. I was chief scientist on the experiment, which was land-based, and someone else from my lab, acting as chief engineer, was responsible for the instrumentation. We were to deploy a spar buoy as our major instrumentation platform during this experiment. I was working on the software for the system when one of the technicians came in to tell me of an argument on the dock. I went out to find my chief engineer arguing with another engineer involved in the design of the spar about how much flotation to bolt onto the structure.

This was a serious argument. A spar buoy is a long vertical pole with flotation in the middle and a weight at the bottom. The amount of flotation is finely adjusted so that the spar will float vertically in the water, with a fixed amount of the pole sticking up out of the water. The excess pole sticking out of the water acts as reserve buoyancy for the system, balancing any tendency for the spar to sink. For example, the APL wave spar my engineers were arguing over, was 12 m long and weighed over 900 kg in air, but had a reserve buoyancy of just 10 kg per meter of submergence. If enough buoyancy is not placed on the spar when it was deployed, then it would sink to the bottom. This particular spar carried about $100K worth of instruments, so its loss would have been rather substantial.

I tried to calm the argument by suggesting that we could calculate how much buoyancy was needed with a set of careful measurements. But we first needed to know how much the spar weighed in air. I was appalled to find out that nobody could tell me. Without an accurate weight, there was no way to make any kind of estimate. I decided on the spot to add every piece of buoyancy that we had brought along. I had the smallest pieces of buoyancy attached using tie wraps so that a diver could cut them off easily if there proved to be too much buoyancy. I figured we could use the removable buoyancy and add weights to balance the structure after it was placed in the water.
Confident that we had enough buoyancy on the spar, we put it in the water at the pier and towed it several kilometers to the test site. I sent out a technician and a diver in a small boat with the spar to check its buoyancy. When they got 10 m away from the boat I yelled across to the technician to let the spar float, but not to let go of the line we had attached to the spar. He heard the first part correctly, but missed the word ‘not’ in the second part. As he tossed the line over the side of the zodiac, both the spar and my heart began to sink. The spar’s natural period of oscillation is about 16 seconds so its downward motion was agonizingly slow. I yelled until I was hoarse, and our technician just managed to maneuver the zodiac around and grab hold of the spar before it slipped beneath the surface. Actually I think the spare buoyancy in the telemetry box at the top of the spar would have prevented it from sinking, but it came awfully close. In the end we had to borrow some additional floats from the small work boat we were on to complete the deployment.

Ever since this episode, I personally have assembled and weighed the spar back at our lab prior to shipment. I have measured the volume of every piece on that spar and can estimate within a kilogram or two how much buoyancy we need to make it float at the proper level.

From this experience, along with others, I now am careful to distinguish between the delegation of work and the delegation of responsibility. As test scientist I was responsible for coming back with the data. Our sponsor didn’t want to hear that we had lost a buoy because of a mistake made by one of our engineers. He would not have cared that it wasn’t my fault. Since then I have learned that one must delegate the work, but that the responsibility lies with the scientist. For that reason, I either do critical pre-test checks myself, or I rely on people that I can absolutely trust. I try to leave nothing to chance.

The Effects of Poor Preparation

Finally, I’ll relate a story that did not end happily. As a favor to a friend, I signed up for a cruise in the Pacific. My friend was the chief scientist for the overall test and was concerned about one of the ships involved, which was to make environmental measurements. The problem was that there were no APL scientists on board, just technicians and engineers. I signed on as an environmental consultant just to help out my friend.

A primary instrument on this cruise was a downward looking Acoustic Doppler Current Profiler (ADCP). It was to be operated by an engineer who had previous experience with such systems. I arrived at the dock just two days before we were to sail. The instruments had already been set up on the ship and a few-hour long shakedown cruise had been completed to test the instruments. I was told that the ADCP had been fully tested and was working just fine.

We set sail for an area several hundred kilometers from Hawaii under rough conditions. Not one for heavy seas, I was sick in my bed for the first three days. When I finally could get up and about I checked to see how the instruments were working. Everything was working fine but the ADCP.

It seemed that everyone but myself and the engineer responsible for the ADCP had shown up for the onload and installation a week prior to sailing. I was late because of another test, but the engineer had been vacationing on the islands. By the time he finally decided to show up, the technicians were mad about having to do his work. Instead of facing the constant wrath of the technicians, the engineer decided that he’d install the system himself.

Once I had reconstructed this history from the participants it took us a few hours of work before we were finally able to determine that the engineer had miswired the stepper input
from the directional gyro. When we rewired the system correctly it began to work. To my way of thinking we lost several days of data because of this engineer’s lack of preparation and dedication to his work. I was most bothered by the fact that he had assured me that the system was working fine and that the shakedown cruise data looked good. It was only later that I found out that he hadn’t processed the data completely when he gave me this report. It was for that lie that I have sworn not to go to sea with him again.

An Example Preparation Checklist

Preparation of your instruments is one of the keys to success at sea. This lesson cannot be overstressed. Naturally each instrument is different, but as an example, here are the procedures I now go through to deploy our APL wave spar buoy with 3 wave gauges, current meters and meteorological system.

Wave Gauges

The buoy system uses three wave gauges designed and built at APL. These system use a homebrew anodized tantalum wire sensor which has proven to be sensitive, extremely linear, stable and rugged. The capacitance of the sensors, which is linearly related to water level, is measured and converted into a voltage within a small electronics assembly.

1. Though each wave gauge uses only a single wire sensor, I typically take a dozen or so sensors on each cruise, in case the sensors are broken or damaged in some way. We manufacture each capacitive sensor using a simple anodization process. The sensors are cleaned, aged in a salt-water solution, and then calibrated. The calibration values are saved in a notebook that is kept at the lab, and a copy of the calibration is included in the bag where the sensor is stored prior to use.

2. Though each wave gauge uses only a single electronics assembly, I usually prepare four or five units for the field. Each unit is cleaned when removed from storage. Each electronics package is powered up and tested for proper operation. An input current as a function of operating voltage is measured for each unit to look for failures and to test the unit’s stability. I have known buoy system’s to fail due to excessive current draw from a single instrument, so I always check the current draw of every instrument on the buoy.

3. The seals on each assembly are checked and resealed if questionable.

Finally the wave gauges are each calibrated and adjusted so that their capacitance-to-voltage transfer functions are linear and nearly identical. These like-calibrations make their replacement in the field easier. All calibration data are stored. When questions arise during, or after a test, it is then easy to perform post-test calibrations on a particular instrument and meaningfully compare these with the pre-test calibrations. Good instruments don’t drift.

Current Meters

The spar buoy can accommodate up to three current meter / CTD packages. We use a UCM-40 Mk II current meter manufactured by NE Sensortec of Norway. These units are rugged, low power three-axis acoustic current meters with a resolution of 1 mm/s with 1-second integration time. All communications with the units are provided via an RS-232 link to a controlling computer.

1. Retrieve current meters from storage and clean. All units are powered up and tested for coarse operation in a bucket of water. Operating current versus operating voltage is measured and compared with specified values.

2. Each unit is taken apart and the internal clock battery voltage is checked. The batteries are replaced if necessary. O-rings are cleaned and regreased before reassembling the units.
3. The temperature and conductivity cells in each unit are calibrated using a stable bath and a conductivity and temperature reference system that we have at the lab. Adjustments are made to internally stored coefficients to bring the units into specification. Past current calibrations, using a stable flow tank and a laser Doppler velocimeter for reference, have shown that the units are stable with time, so this more complex test is not performed each time.

4. The setup parameters for each instrument are planned and written down. Each instrument is powered up and setup for their operation in the field. All of the status and setup information is then downloaded from the instruments and recorded into a file for future reference. This can be very useful in insuring that the operator has not changed the settings accidentally. From this point on, all communications with the instruments are recorded. This setup includes measurement timing, averaging lengths, designation of channels to be reported, setting of magnetic deviation in the area of the test, and a variety of other instrument specific variables.

Meteorological Systems

1. System is retrieved from storage and cleaned. All anemometer bearings are checked and replaced if necessary.

2. The system is powered up and current is measured. Each sensor is checked for proper operation, including temperature, humidity, wind speed, direction, and compass. Detailed calibrations of each sensor are performed.

Wave Spar Control Computer/Telemetry System

All instruments on the spar are connected to a homebrew control computer and telemetry system. This system allows the user on a nearby ship to control each individual instrument, and read data from the instruments in real time. The system can also be programmed to serve in a store and forward mode where the data from the instruments are stored for later forwarding to the ship. This system includes the control computer, a spread spectrum RF telemetry system, a remote controlled instrument power distribution system, and cabling.

1. The control computer and telemetry system are powered up and tested. A backup external direct connection to the computer (in case the telemetry system fails) is tested. Input current for the entire system with and without telemetry system is measured.

2. The remote control power distribution system is tested by turning on and off each and every system while checking each connector for the proper DC voltages.

3. The entire system, with all instruments and cabling, is wired together in the laboratory for testing. Each instrument is tested individually. All of the instruments are then tested in unison. The store and forward capabilities are tested. Typically an overnight test is then run and analyzed for any discrepancies or data glitches that could represent system problems. Any new features that have been added to the control firmware are given special attention. The system is powered on and off repeatedly to insure that all of the instruments and control computer start up correctly. Total system current is measured and compared with expected system totals.

Spar System

The entire spare system is then assembled, including all hardware, instruments and cables. The battery systems are charged and discharged to measure their capacity, replaced if necessary, and then recharged. All hardware is checked to insure that it is painted or anodized aluminum or stainless steel. The system is checked for operation and all cabling is dressed with tie wraps and duct tape (the oceanographer’s friends). The entire system with and without flotation is then weighed. The individual flotation elements are weighed.

When the system is completely ready to go and fully operational, the area is cleaned of all debris and parts. An empty table is set up nearby to accommodate the tools and parts during the disassembly.
The spar is then carefully disassembled with each set of screws, nuts and bolts going into labeled zip lock bags. All of the hardware, instruments, cabling, and bags of fasteners go into the shipping boxes. This procedure insures that when the boxes are opened for deployment that all of the parts will be present for the proper assembly of the spar.

Finally a deck box containing spare hardware and fasteners along with expendables like tie wraps and tape is prepared. This is shipped along with the spar just in case we missed something or in case we decide to change the spar configuration at the last minute. I always take spare instrumentation support arms into the field in case we decide to add something. I have even designed spare unused channels into the control computer for such an eventuality. I don’t forget to take an assortment of spare underwater connectors and cables, along with a wide variety of other stuff that just might come in handy.

Finally, all of the documentation for the spar including mechanical drawings, electrical and electronic diagrams and schematics, connector wiring diagrams, firmware and communication documentation, power measurements, weights and volumes charts, and instrument calibrations are bound together into a single notebook. Multiple copies of some drawings are included just to insure that the information is still available if a document is removed from the book in the field and lost. Included with this book is a mosaic of photos taken of the entire assembled spar showing the location of each and every part and bracket. These photos, taken just prior to disassembly, make the reassembly of the system that much easier. They also come in handy two years down the road when you need to reassemble the system after it has been in storage.

While this checklist is quite specific, a more general checklist for instrument preparation is easily constructed:

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**Know Your Instrument**

There are few absolute rules in this book, but this is one of them. A complete understanding of the operation, care and feeding of your instruments is a must for successful operations. If all goes well, your knowledge should not be needed, but things rarely go well at sea. When conditions change, things break, or just don’t work like you planned, your knowledge of your instruments may well determine your ultimate success or failure.

In 1989 I was involved in a collaborative effort with Dr. Guy Meadows of the University of Michigan to measure the surface currents in the wake of a large ship. While this is not an easy task, our approach was a simple one. We decided to seed the wake with small drifting flares. The location of these drifters would then be tracked using a video camera mounted on a helicopter hovering over the wake. Because I was already planning on using video to image the ship wake for other reasons this was a natural extension of my efforts. The only necessary addition to my planned system was a means of measuring the pointing direction of the camera. (I already had made provisions for recording altitude.)
After asking around, one of my colleagues at APL recommended that I use a vertical reference gyro to measure the helicopter roll and pitch. Best of all, he knew where we could borrow one. I made all the arrangements and was soon the proud proprietor of a vertical reference gyro. The owner had thoughtfully provided us with wiring schematics for the gyro, so I passed the whole mess to a technician who was working with me on the project. I explained to the technician what I wanted and asked him to find the correct power sources for the gyro and to wire it into the system.

A few days later I got a call from the technician. It seems that this particular gyro required an inordinate number of special voltages. The technician had managed to find the required 28 volts DC and the required 115 volts 400 Hz AC, but he didn’t have an easy solution for a 12 V DC input. I suggested using a small DC-DC converter as the current was not great, but time was running out and we had a million other things to get ready before the test. The technician suggested that maybe we didn’t really need this voltage after all. It turned out that he had powered the system up without the 12 V supply and it seemed to work fine. Furthermore he had taken the gyro apart and had traced the 12 V line to a switch that was activated when the gyro was in the vertical position and a small sealed block that he took to be a resistor. He had come to the conclusion that this 12 V input was actually an indicator of when the gyro was vertical. It all made sense to me, so I agreed that we should just skip the 12 V power supply.

Two weeks later, the system was installed in a helicopter in California and we tested it out. Everything worked fine on our first, short test flight. The next day the experiment began. About a half an hour into the measurements, I noticed that the aircraft pitch and roll looked funny. As I watched, the computer indicated that the helicopter rolled onto its side and stayed there. I was having no trouble sitting on the floor of the helicopter and so I knew there was something wrong with the instrument. I powered the system down, latching the gyro into the vertical position. Then I powered the gyro back up, and unlatched it. Over the next half hour the gyro again drifted so that it indicated the helicopter was flying on its side. No matter what I did, I could not get the gyro to work correctly.

When we landed we checked out the whole system and it seemed to work fine. The gyro only had problems in the air. Furthermore, we had no spares (another no-no) and could locate no one that seemed to know anything about this particular gyro. We struggled with the system for two weeks, but in the end, the portion of the experiment that required this gyro was lost.

When I returned to APL I decided to do some reading about vertical reference gyros to try to figure out what went wrong. I read that a vertical reference gyro is simply a gyroscope that is set in a dual-gimbaled mount. The gyro is spun up with the mount locked so the gyro shaft is vertical. Only when the gyro reaches full speed are the gimbals released. Sensors on the gimbals then measure the angle of the gyro shaft, which remains vertical, with respect to the case that is bolted to the aircraft. That is at least how an ideal vertical reference gyro works. In the real world of course there is friction and so a real gyro will slowly rotate away from vertical, or fall over, unless it is somehow occasionally forced back to vertical. The scheme for doing this involves a switch that is thrown when the shaft is nearly vertical and small righting magnets that give the gyro a small tug as it passes through vertical. This scheme, which relies on the fact that on average the aircraft has zero pitch and roll, acts as a low pass filter to keep the gyro erect. That damn 12 V supply which we didn’t bother hooking up was the power for the righting circuit. Without it, as soon as the aircraft performed any maneuvers to bring the system out of level, the gyro would begin its slow fall.

It was an expensive lesson. We came back empty handed and I couldn’t blame Guy if he decided to never work with me again. But it was a valuable lesson and I have taken it to heart.
Now I try to learn as much as I can about every instrument that I use. I study the principles of operation. I read and reread the operations manual. I practice setting the instruments up in the lab. I do everything I can to insure that the instrument will work in the field, and that if it fails, that I know enough to either fix it or at least diagnose the problem.

Knowing your instrument may also prevent mistakes from being made in the interpretation of data. No instrument is perfect. They all have limitations and ranges of validity. Scientists who believe everything that their instruments tell them will typically have short careers.

A few years ago I was involved in an experiment off the Eastern coast of Scotland in the Sound of Sleat. The experiment involved several moorings, but this was the first time we had operated in this region. Realizing the risk of mooring in a new area, the chief scientist wisely deployed a bottom-mounted ADCP in the area about two weeks prior to the deployment of the moorings. When the ADCP was recovered prior to the experiment, it could provide us valuable information about the currents in the area that might be used to improve our moorings.

When the ADCP was recovered, the data were dumped and analyzed by a young scientist who was responsible for the instrument. When I asked him about the results he explained that the peak currents were 5 cm/s or less throughout most of the water column, but that the near-surface currents got extremely large, often exceeding 1 m/s! These results surprised me. I asked him how close to the surface these strong currents were observed. When he told me that these extreme currents were limited to the upper 5 to 10 m of the water column in an area where the total water depth was 80 m, I understood exactly where he had made his mistake.

ADCPs work by sending out beams of acoustic energy and listening for the backscattered energy along these beams from small bubbles or particulates in the water. The Doppler shift of the backscattered energy gives a measure of the fluid velocity towards or away from the ADCP. A typical unit will send out four beams, in a so-called Janus configuration. The four radial velocity measurements are then combined to estimate the horizontal and vertical components of the velocity.

In real life, the beams produced by the ADCP are not perfectly collimated. Because of limitations in the size and design of the acoustic transducers, the beam pattern has sidelobes, which contain energy propagating in directions other than the desired one. While the sidelobes are very weak, so is the scattering from particulates in the water. As long as the main beam signal is stronger than the sidelobe signal, the system works. When the beams from a bottom-mounted ADCP approach the surface, the sidelobe reflection from the surface becomes stronger than the backscatter from the main beam and the ADCP readings are contaminated. [For a detailed description of the process see Acoustic Doppler Current Profilers, Principles of operation: A Practical Primer, 1989 by RD Instruments, Inc.] RD Instruments suggests that the upper 15% of the range bins from a bottom-mounted ADCP should be discarded as unreliable, although this is just a simple rule of thumb for a rather complicated phenomenon.

With this understanding of the instrument as background it was easy for me to see what was wrong with the reported measurement. I pointed out the problem to the young scientist but he refused to listen. He excitedly explained to me that the instrument reported a quality value with each measurement, and that these near-surface measurements were of high “quality” and thus could not be wrong. The quality measurement that he referred to is a measurement of signal strength and so would not indicate a problem due to near-surface sidelobe contamination, which is a strong signal. I argued with him for a few minutes but I
could not dissuade him. Unfortunately this type of unshakable faith in data is far too common an occurrence.

I explained the problem to the senior scientist on the experiment, and he understood immediately. Several days later, for my own amusement, I considered the ramifications of my young colleagues interpretation of the near-surface ADCP data. The Sound of Sleat is relatively open to the south, but connects again to the sea to the north through Kyle Rhea, a narrow channel of water between the Scottish mainland and the Isle of Skye. If the reported surface currents were accurate and if they extended over the entire mouth of the Sound then it was easy to compute the flows required through Kyle Rhea to achieve mass balance. The answer was over 30 m/s which I took to be just a tad high!

A good scientist not only understands their instruments but also questions every piece of data returned by those instruments. A typical trip to the movies or the theater involves a willing suspension of disbelief to enjoy the show. When considering data from field instruments you want to do just the opposite: you want to accentuate your disbelief. Only when you have been convinced that nothing is wrong with the instruments, or the way they are being operated, should you truly believe your data.

Redundancy

Always carry spare parts, spare instruments and spare computers. In fact, if you can, just take a spare for everything. On any given experiment it is not of question of if something will fail, it is a question of what will fail and when.

Here is what Sir Wyville Thomson of the Challenger Expedition in 1873 had to say on the subject (as quoted by Menard):

It is almost inconceivable how difficult it is to keep instruments, particularly those which are necessarily made of steel, in working order on board a ship; or how rapidly even with the greatest care they become destroyed or lost. For this reason it is necessary to have an almost unlimited supply of those in most frequent use, such as scissors, forceps, and scalpels of all sizes.

On a recent program I thought one of my acoustic current meters would make a great addition to a towed catamaran system that had been developed by some colleagues at Woods Hole. The designer of the catamaran wasn’t easily convinced. We had never worked together before and I’m certain that he was a bit afraid that I would try to take credit for his new system. To convince him that I wasn’t a threat and that the current meter would make a nice addition to his platform, I sat down and wrote out all of the reasons that the current meter should be added. I then wrote down my proposal for an agreement about how the data would be shared from the systems on the catamaran (see the section on collaborations).

My presentation won my colleague over and he agreed to include the current meter on his catamaran. I thought it strange, though, that he argued strenuously with one of my rationales for including the current meter, and that was redundancy. The measurements on the catamaran depended critically on knowing the orientation of the entire system. I argued that the current meter’s built-in compass and tilt sensors could act as a nice backup to the catamaran’s primary motion and orientation sensors. My colleague explained to me that my tilt sensors were not accurate enough (he was right) and that he had already built in two compasses. Still, my other arguments carried the day and the current meter was integrated into the system.
After a couple of days at sea, we began to realize that the main compass on the catamaran had failed. Whether it was due to damage in handling or some electrical problem I couldn’t say. There were no spares for the primary compass, but we still had the secondary compass. A few more days passed and we started noticing that the secondary compass was drifting in some strange way. I discussed the problem with my colleagues. I was familiar with the compass they were using (see the previous section on knowing your instruments) so when they explained to me how the system was calibrated I knew what the problem was. They were using a small flux-gate compass with integral microcontroller. The microcontroller supported an automatic calibration mode that would recalibrate the compass when it passed through a 360° turn. I had used one of these compasses before and had spent some time figuring out how this auto-calibrate mode actually worked. My colleague at WHOI had read the manual and figured that if calibration was a good thing, then constant recalibration must be even better. He had locked the compass into a constant recalibration mode, so each time the catamaran would make a full circle, the compass would recalibrate itself!

Unfortunately, there was no way to undo the setting to the secondary compass in the field. Fortunately though, we had a backup to the backup compass inside my current meter. That compass essentially saved the entire scientific content of the catamaran system.

Of course redundancy should not be restricted to primary measurement systems. I always take a few general-purpose items along with me just in case they come in handy. For example, I always take one or two adjustable laboratory power supplies along with me. Power supplies are a common failure point in modern electronic systems. I can’t provide a spare for every system, but a lab supply can be used to replace a faulty power supply in a pinch. In 1989 I was providing ground-truth measurements for a radar remote sensing experiment in a Scottish loch. Our equipment was all working, but I had heard that one of the other organizations had a problem with their radar. When I asked if there was something we could do to help out, I was told no, not unless I happened to have a spare ±15 volt power supply lying around. Well it just so happened that I did and the radar was fixed without a costly delay of several days in finding a replacement. The owners of the radar were amazed, but to me it is just common sense to take along not only everything that you need, but also everything that you might need.

I know that this may seem excessive, but I pride myself in taking along enough spare items that I usually end up helping out someone else’s experiment as well as my own. The value of the reputation that you can develop by coming to the aid of your colleagues on an experiment cannot be underestimated.

I’ll end this section with one final embarrassing story about the only time that I came back from an experiment totally empty handed. It was the second worst experience of my professional life. (The first was a disastrous presentation to a sponsor early in my career that to this day I don’t want to talk about.)

Some colleagues at another laboratory built a large current meter array for measuring near-surface shears. Prior to them building this array I had pointed out that the S4 current meters that they had chosen for the array would not work because of magnetic crosstalk. S4s are electromagnetic current meters. They work by creating a magnetic field about themselves and then sense the voltage induced by the motion of the conducting sea water through this field. In order to separate out the S4’s magnetic field from that of the Earth, the designers made the S4 field alternate polarity at a fixed frequency. When a pair of S4s are separated horizontally, they detect each other’s fields and the resultant cross-talk can swamp out the current-induced signal. I had personally made this mistake before and knew they would have problems. My colleagues chose to ignore my warning. They had been told by the factory that this would not be a problem and they believed the factory instead of me!
[While this is an aside, there is a good lesson to be learned here. Always be suspicious of salesman. One of my colleagues at APL talks of catalog engineers. By this he means those people who believe what they read in the catalogs, design their equipment based on the published specifications, and then are surprised when things don’t work as they planned. While most businesses are quite honest, the goal of all businesses is to sell product and make money. It is rare to find companies that will disclose the limitations of their own equipment, but there are a few. When faced with the choice of believing a scientist who claims a problem exists or believing a company’s denial, I tend to believe the scientist. Many corporate claims can be easily dismissed if you understand enough about how their instrument works and ask enough questions. A company that answers all of your questions honestly and admits to the shortcomings of their instrumentation is a good one with which to do business. And frankly I give the same advice for buying stereos as for oceanographic equipment.]

It turned out that the crosstalk of the S4s on this array was so severe during the first deployment that the data were essentially useless. My colleagues then took the problem back to the factory, which modified the instruments to work on different frequencies to minimize the noise. At a presentation after the first experiment, but before the second experiment with the modified S4s, I again expressed reservations about the system. This time I was willing to put my money where my mouth was and offered to come along and add three of my ultrasonic current meters to their array to allow for a side-by-side comparison. To my surprise, they agreed to my proposal.

The experiment was a small engineering test, although given the size of the array and the number of people required to feed and tend it, the costs of the total test must have run at least $300K. My part of the test was a small add on which I estimated cost the sponsor about $30K, total. The relative costs become important later on as we shall see.

When I arrived, the array had already been assembled on the dock and the S4s were being installed. My colleagues had manufactured some mounting brackets for my instruments so it only took me a few hours to install my instruments. Overall I installed three current meters and the control and telemetry system from the APL wave spar onto their array. The control and telemetry was a bit over-engineered for this application, but it was already built and could easily handle the load of just these three instruments. Unfortunately, I made a terrible mistake in installing my system. When I assembled the control system, the rubber seal slipped as I was closing the cover, leaving a small gap through which water could enter. On the dock the defect went undiscovered and everything checked out fine.

The same could not be said of my colleague’s system. They had ten S4 current meters multiplexed together into a single data stream by a control system that had been built specifically for this purpose by InterOcean, the manufacturer of the S4. The single data stream then fed into an RF modem for transmission back to the nearby ship. After some initial testing showed the system was ready to go, the array was hoisted into the water. The next day, just before beginning our tow, a set of newly charged batteries were swapped into the system on the array. Unfortunately, something then went wrong, and the system went dead. The exact reason for the failure was never discovered, but in the end the entire telemetry system had to be lifted back onto the dock and the deployment delayed. During this period my system continued to check out fine, so I pestered the technician working on the array telemetry problem with offers of help. After a full day of troubleshooting with no progress to show, my offers of help finally rubbed him the wrong way and we argued. I told him that when he finally gave up, I’d fix the system, but not a minute sooner. He went back to his work and I went off to have a beer.
Two more days passed, leaving just five days out of a planned eight-day test. Finally, I heard that the technician had diagnosed the problem as a bad telemetry transmitter. Unfortunately, he had no schematics for the unit (the manufacturer contended that the design was proprietary!) and he had no spare units or parts. He gave up. I went to the shop, asked him if I could fix it by replacing the entire telemetry system with a spare that I had. Given nothing to lose, he agreed.

The only problem I encountered in replacing their system was that my telemetry system required RS232 signal levels and the control computer had only a TTL-level interface. Fortunately I had some spare level-shifting ICs in my kit. So I wired up a small interface board in the shop. It looked like hell but it worked. I then put duct tape all around to insulate the board from its surroundings, taped it to the top of my spare telemetry system and taped the whole mess to the inside of their box. It was an ugly rats nest of wiring and duct tape, but it worked! From beginning to end I had taken about three hours to get their system up and working.

My plan for sharing the system was simple. I had three telemetry systems. One was in my telemetry box, one was now in my colleague’s box on the array, and one was on board the ship. The plan was to set up my system at the beginning of the day’s measurements to store my data internally. I would then switch off my telemetry system, switch on their system, and they could record their data in real time. Then at the end of the day we’d turn off their system and power mine back up so I could dump my data.

Unfortunately, when we arrived on station, my telemetry had taken on a few drops of water (its amazing how poorly electronics and sea water mix), and it no longer functioned. After some work and few spare board swaps I did manage to get everything in the system working but the data memory board. I had a backup for this board but I was missing one critical IC that I had robbed from the board months before in the lab for another project and had forgotten to replace. Thus I could get the system to communicate in real time, but I couldn’t get it to store any data. There was thus no way that my colleague’s system and my system could both work. To this day I am angry at myself for getting into this situation, but I made the only decision I could. I decided that they could use the telemetry system and my system would stay off. To my colleagues’ credit they offered to share the channel with me, alternating between their instruments and my instruments, but this wasn’t right. It was their experiment and their system was primary. I was supposed to be a low cost, non-interference add-on that was justified in terms of a comparison with their instruments. I made the decision that they should make full use of the telemetry channel. Though I came back empty handed, I’d make the same decision again.

The lessons from this story are many. If I had been a little more careful with the assembly of my system, it would not have leaked. If I had a full spare memory board with me then I could have repaired the system in the field. Also if I had a fourth telemetry package with me (I actually owned a fourth system, but it was broken at the time) then I could have set up two parallel channels. In the end I had enough spares to fix one problem but not both. Everyone I have subsequently told this story to have told me that I did the right thing, but in the end I came back empty handed. I was the one who suffered from the defeat. Just one more spare would have saved me this embarrassment. Take heed, because it can happen to you.
### Instrumentation Checklist

- Gather the opinions and aid of experts when designing instruments, buoys, moorings or just about anything else when going to sea
- Expect things to fail, so examine critical components and single point failure modes
- Prepare for deployment using an instrumentation preparation checklist
- Completely test, characterize and calibrate every piece of equipment
  - Check power draw and thermal sensitivity against design specs
  - Assemble and test complete systems
  - Test for periods comparable to deployment, if at all possible
  - Check all batteries and replace if questionable
- Keep all parts together and labeled when packing
- Pack all require documentation
- Always pack spares of everything
Chapter 6. Data Acquisition and Analysis

Typically getting the instruments successfully deployed in the field is only the first half of the battle. The second half is to acquire, record and analyze the data from these instruments. Usually these data will have to be combined with data from other instruments, so timing of the data streams can become important. These data are incredibly expensive to obtain. The volume of data from a typical multi-million dollar experiment may amount to anywhere from just a few hundred kilobytes up to a few hundred gigabytes. You can’t afford to lose the data once it has been acquired so you’ll need to consider schemes for protecting and backing it up. Finally, there are various levels of analysis to be considered, including analysis done on board and quick look analysis performed back on shore to validate the data set prior to distribution to others.

Timing

Timing should be easy. Man regularly measures time to the sub-nanosecond accuracy. Timing seems to be easy. After all, every computer built since the Apple II has a clock built into it (actually since the Apple IIe). Timing often turns out to be a problem though, precisely because it seems so easy. People rarely devote the time and effort to timing that they should. I cannot tell you how many times I have seen allegedly mature scientists synchronizing their systems to their wristwatch. This is almost never adequate!

The importance of experiment-wide timing solutions and planning has already been discussed in the chapter on preparations. In this section I discuss some of the details of how to provide timing for individual instruments and data acquisition systems. The key in data acquisition is to understand what your timing requirements are, both for individual as well as joint data streams, and to include timing data in the data streams so that these requirements can be met. The same golden rule that guides instrument design (a belief that something will fail) should guide your design of timing within your data acquisition system.

Requirements

Timing requirements depend on the rates of the data involved and inter-system synchronization requirements. If you are on a cruise making CTD stations every hour, then accuracies of several minutes may be all that is required. If, on the other hand, you are acquiring high resolution temperature chain data on one system, and ship roll on another, with the plan to later merge the two data streams, then the timing requirements will be set by the roll period of the ship which may be on the order of a few seconds. In this case the timing accuracy should be sufficient to insure a small phase difference between the common fluctuations in the two data streams, leading to a timing accuracy requirement of less than a second for a moderate-size vessel. At the other extreme, consider the problem of comparing radar backscatter with video imagery of breaking waves. In this case the timing accuracy will be set by the rates of breaking wave evolution, which has scales of less than a second. Timing accuracies for such a system would then have to be an order of magnitude better than the fastest phenomenon and hence be measured in the tens of milliseconds.

When deciding on the timing accuracy requirement for a particular system, always consider the fastest data stream that might possibly be combined with this system’s data. Disk storage is cheap, so when in doubt, it pays to acquire data at higher rates and specify better timing accuracy than you might otherwise deem necessary. As my friend, Michael
Paulkovich, has pointed out (Paulkovich’s Rule of Resource Margins): “Whatever you think
you need, triple it; then add a fudge factor. (And this will still not be enough.)”

Sources of Time for Data Streams

Timing information for a data stream is typically obtained from the instrument itself, the
data acquisition computer, or an external clock. Timing derived from the instrument or data
acquisition computer usually suffer from similar accuracy limitations, while external clocks
range from poor to more accuracy than any experimenter will ever need.

Many modern instruments are internally computerized and provide their own time signals
within their output data streams. Data from less able instruments are often time tagged using
time information derived from the computer clock within the data acquisition system.
Invariably both of these alternatives rely on a quartz crystal oscillator of one sort or another,
and both suffer from the same limitations of accuracies. In the field, my rule of thumb is that
the standard quartz crystal oscillator can drift as much as 10 seconds per day. The causes for
this drift are elucidated below. While this is a worse case estimate, you should count on it.
(Remember Murphy’s Law.)

If you need more accuracy, then use an external clock. External clocks can be oven-
stabilized quartz clocks, cesium clocks, or satellite clocks. For oceanographic work, GPS-based
clocks can provide accurate timing and navigation, so they are hard to beat. If you go this
route, just be sure to use a GPS receiver that is designed for timing. The cheapest GPS
navigation receivers that you can buy use asynchronous computer designs that spit out the
navigation and time information when the relatively slow internal computer gets around to
it. These systems, which can be off by up to several seconds, are not suitable for high
accuracy timing. It doesn’t cost much more to buy a GPS receiver designed to provide
accurate timing.

Clock Drift

Above, I mentioned an outrageously large clock drift value of 10 seconds per day for
quartz crystal clocks. I can hear your objection now, because I have heard it many times
before. You are thinking, “The clock in my PC (or Mac, or Unix workstation) has never
drifted that much.” I am sure that you are right. In the office, a PC system clock usually is
good to few seconds during a month. In the field though, that exact same clock can exhibit
significantly worse drift. Quartz crystal oscillators are amazingly good at keeping time, but
they have well known dependencies on operating voltage and temperature. In the office, the
line voltage and ambient temperature are well regulated. This is in sharp contrast to the field,
where line voltages and ambient temperatures can fluctuate all over the place. Quartz clocks
in the field are never as accurate as those in the office.

In addition to quartz oscillator drift, the common IBM PC has another, sometimes more
dangerous clock problem built into it. Within a standard IBM-compatible PC there are two
clocks, the CPU system clock and a real time clock. The CPU system clock is maintained by
software from the quartz oscillator that drives the CPU. The real time clock runs from a
separate oscillator within the computer. When you use the lowest-level system calls to obtain
the time, you are actually reading the CPU system clock. The problem is that this clock,
because it is maintained by software, can occasionally miss a tick if the system interrupts are
turned off for any length of time. Most programs do not turn off the system interrupts so
this is rarely a problem for the typical user. Unfortunately, scientific users are not typical.
One of the only classes of programs to turn off system interrupts are those that need to
maximize their response time to external events, such as data acquisition programs. This is
not good! The problem is so severe that I have seen data acquisition systems lose minutes per
day because of a reliance on the CPU system clock that was missing ticks due to the data
acquisition system design. While software can be designed to use the system clock without
losing ticks, I prefer to invoke a few more software commands to rely on the real time clock
instead. It will suffer the same drift that all quartz oscillators due, but it won’t drift according
to the CPU loading.

Solutions

Many of the experiments that we go on require timing accuracies of on the order of a
second or two. A typical solution for us is to take a GPS or GOES clock along on the
experiment. The RS232 data output from this clock is then piped around to all of the
computer data acquisition systems. (The RS232 outputs from the computers are left
unconnected.) The individual data acquisition systems are designed to rely on the internal real
time clocks, but are set up to periodically set the real time clocks from the serial time stream.
This design synchronizes all of the data acquisition clocks automatically and has the
advantage that the systems will continue to work if the satellite clock fails.

For even higher accuracy timing, specialized boards are usually needed or efforts have to be
made to design the higher accuracy timing directly into the instrument output data
streams.

On a related topic, you should carefully consider those data streams that you know will
have to be merged after the experiment. A good rule of thumb is to record such data streams
onto the same data acquisition system, interleaving the data streams to be combined into the
same file. The alternative design, of using two separate data acquisition systems, requires that
the timing within both systems be accurate. If, on the other hand, the data are interleaved
into a single file, then the data can be merged after the experiment, even if the timing data
are lost.

Backup

I have stressed the dollar costs of performing an experiment at sea. If you have been to
sea you also know the personal costs – the time spent in preparation and execution can be
immense. Because of these costs, the digital data that you acquire at sea are incredibly
valuable. These data are invariably recorded on some form of magnetic media, either disks or
tape. When we add to this the simple fact that all magnetic media will eventually fail, then
we have a possible recipe for disaster.

You may think I exaggerate. Typical lifetimes of data on magnetic tape run 10 years.
Typical lifetimes on floppies is less and hard drives more. Still, all of these media will fail at
some point. The oxide will flake, the magnetic field strength will decay, or the drive will fail.
Even more of a danger comes from accidents. Something can be spilled onto the media. Or,
fear of all fears, a magnet will come near the media. When I go through airports, I always
fear the X-ray machines. The guards will always tell you that the X-rays are safe and they are
right. I don’t fear the X-rays. I fear the magnetic fields set up by the motors that drive the
conveyor belt. I nearly caused an international incident in the Hamburg airport once when I
refused to allow them to run 80 Gigabytes of data on Exabyte tapes through their X-ray
machine. I know I was being a bit fanatical, but those tapes had cost me a month of my life,
and I was determined to get them home intact.

The solution to the problem of unreliability of magnetic media is simple: you should back
up your data. Typically, I will back up data each day of an experiment onto a separate backup
disk or tape. I fully label these disks or tapes, set their write protect tabs to prevent accidental reuse and keep them separate from the main data disks. At the end of the experiment, if the volume of data is not too great, I’ll then combine all the data from the main disks onto a few tapes or disks. I then hand carry these summary tapes back home. I always carry one set back and ship the other. That way if the shipment is lost, or my prize data and I get run over by a pizza delivery guy, then at least one set of data survives.

Data backup is not hard. While the risk of data loss on modern media is small, a backup plan should be a part of every experiment.

**On Board Analysis**

It used to be that scientists would go into the field, acquire their data, and then go back to their labs to perform the analysis. This separation of the acquisition and analysis phases was dictated by the lack of computing power and time on board the research vessel. While I won’t suggest that all analysis needs to be done on board, especially for those systems whose data are inaccessible like deep moorings, it is of critical importance to perform some on board examination of the data that are available.

There are two reasons for this desire to perform on board data analysis. First, and foremost, you can best determine if your instruments and system are working if you analyze the data. I have seen the anguish of scientists who discovered that mistakes were made in the field months after the experiment was over, and it is not a pretty sight. In this day and age there is no reason for this. I think it was Archimedes that said that if given a sufficiently big computer and a place to stand he could rule the world. (Or was that a slide rule?) Now we have that level of computing power available to us on a desktop along with advanced data analysis languages such as Matlab or IDL. Your goal here should be to perform sufficient analysis to insure that your instruments are working and that you are acquiring data of sufficient quality and quantity to satisfy the needs of your final analysis.

The second reason for on board data analysis is to provide data to guide the conduct of the experiment. For example, I regularly perform a detailed real-time analysis of CTD data during experiments involving internal waves. Calculation of the solutions to the Taylor-Goldstein equations provides information regarding both the vertical structure of internal waves trapped in the pycnocline as well as their dispersion relation. The dispersion relation is then used to better estimate the timing of key observations of internal waves, thus affecting the actual conduct of the experiment.

In other cases, real time data analysis will reveal features that warrant additional investigation. On one test in a coastal environment, I had been regularly examining current data from 3 instruments on the APL spar buoy in real time. When the system was started up on one particular day, I noticed that the vertical channel of the instrument at 3 m depth was very noisy, while the instruments at 1 m and 8 m depth were quiet. I concluded with dismay that the middle instrument was failing. Later in the day, I noticed that the 3 m vertical channel had quieted down. When I looked at all of the current time series for the day, it was clear that the vertical channel at 3 m depth was correlated with especially strong shears at the base of the mixed layer, which happened to be only 3 m deep. I quickly worked up some estimates for the bulk Richardson number, a measure of the stability of the water column, and found a near perfect correlation with the noise at 3 m depth. So instead of equipment failure, I was directly observing the baroclinic instabilities induced by the near-surface current shear. Neat stuff. And even better yet, because I was able to identify the situation, we redoubled our efforts to obtain profiles of currents and stratification to get a more complete picture of this phenomenon.
On the Nova expedition, undertaken in the late 60’s to study the geology of the South Pacific, the goal was to analyze all of the data as it was taken. As Menard put it:

...We expect to analyze all the data as rapidly as they accumulate, which will require a newly developed method of computer handling. If it works, all the preliminary analysis and much of the final analysis of all the millions of observations will be completed by the time the ships return to San Diego. I certainly hope so, not only because it is essential for planning the later parts of the expedition but also because I shall not go to sea again until it is done. American oceanographic laboratories are loaded with undigested observations, and I do not want to be guilty of adding to the pile.

It is useful to recall that of the two ships participating in the Nova expedition, only one was equipped with a computer. Now, with computers everywhere, on board analysis should be simple!

You should be aware of at least two problems with onboard analysis. The first is mental inertia; don’t fall into the trap of treating on board analysis products as the final word on the subject. It is a rare experiment indeed that you can walk off the ship with all of your analysis work done. I am always careful to label on board data results as preliminary and make a point of warning my colleagues about using such products prior to a more complete work up. The second problem is that the analysis results may influence you to alter your test plans in ways that are not actually for the best. For example, if I had done no further analysis on the noisy 3 m current data, I would have continued to believe that the instrument was failing. Since this was an important instrument I might have actually called out a diver to replace the system at some expense and disruption to the experiment. It is all too easy to initially jump to the wrong conclusion. For this reason you need to guard against the use of misleading or incomplete analyses during the experiment.

Goals for Cruise End

My typical goal is to walk off the ship at cruise end with a complete cruise report, containing my cruise logs along with sample data products and analyses performed on board, as well as a complete data catalog. My goal is to have this report on computer, formatted and ready to print as soon as I get back to the lab. I’ll admit that this is an ambitious goal and that I rarely achieve it, but it is good to set your goals high. Furthermore, you’ll need all of this information at some point anyway, so why not try to assemble it all on board ship.

I also find that putting out a cruise report within a few weeks of the end of a cruise works to document the cruise for yourself and your colleagues in ways that handwritten notes and logs cannot. While this report may be full of the blemishes associated with a preliminary effort, it should have all of the detail necessary for someone to evaluate the cruise and the quantity, if not quality, of the data that you obtained.

Quick Look Analysis

The next phase of analysis occurs after you leave the ship. In a typical ONR sponsored experiment, there will be an experimenters meeting within one to two months of the end of the cruise. I usually set my next goals to coincide with this meeting. Prior to this meeting I work hard to complete all pertinent data catalogs. I also perform sufficient analysis to evaluate the quality of my complete data sets. Finally, I attempt to process any general-
purpose environmental data that I have agreed to share with the community to the point that it can be distributed. I refer to this work as quick look analysis. It is only after the completion of the quick look analysis that I actually turn to performing the research that I set out to do.

My approach to the question of priorities here is clearly different than most of my colleagues. On a typical experiment, I will be responsible for a number of measurements. Some of these are quite general in nature, such as wind speed and direction or mean currents, and are needed by all of my colleagues for their research. Other measurements I make, for example high-speed vertical velocity measurements to estimate turbulence, are solely for my own research and are not needed by my colleagues. When confronted with the choice of which to analyze first, I prefer to work up the general-purpose data to the point that it can be distributed.

There are several reasons. First, I typically need the general-purpose data myself for my own research. Second, the general-purpose data typically will be used to select times and environments favorable for the more detailed analysis to come. Thus it serves as a guide into the full data set. Third, I feel that I owe it to my colleagues to produce promised data sets in a timely fashion so that they can get on with their research. It is also good to use this as moral leverage to get your colleagues to work up their data that is of use to you. (I don’t believe in holding data back as an inducement. Remember it’s not really your data, it belongs to the sponsors and, at least usually, the taxpayers!) Last, but not least, I am a notorious procrastinator and so I treat my research as the carrot to get me to do the general work up front.

Naturally I understand that each data set and experimental group is different. On one experiment, it took my colleagues two years to work up the data into a preliminarily useful form! Their data set did contain over 160 gigabytes so I suppose this is not an unreasonable length of time. So as with everything in this book, don’t go overboard on my suggestions. I do suggest though that you treat your commitment to your colleagues as if it was as important as your own work.

One final point on quick look data analysis is worth making. I was on one experiment a few years ago where three different groups measured the wind speed from three different locations about the experiment site. Afterwards each produced time series of the winds that they distributed to other researchers. Naturally none of the measurements agreed exactly, which led to numerous arguments about which wind speed was “correct” for a particular analysis. In a subsequent experiment, we took it upon ourselves to coordinate the wind analyses. A single report was produced which included all of the data along with the locations of each measurement and a mean wind value for the area. This approach eliminated any squabbling about which measurement should be used and at the same time, by intercomparing the measurements, provided a mechanism for checking all of the measurements. Everyone wins when they cooperate in joint analyses.

Data Distribution

I cannot tell you how many programs I have been involved with where the reality of post-experiment data distribution bears no resemblance to the pre-experiment promises of various experimenters. Too often investigators promise sponsors that their data will be made available to their colleagues, only to conveniently forget their promises later. The other out that I often see taken is to provide copies of books of data plots to interested colleagues. I have always thought of this as a cop out, because in this age of the computer, paper copies of data do me little good.
To me, the only good way to distribute data is digitally. I prefer to provide my colleagues with computer data files that they can use in their own analyses. I have personally progressed through three stages in the evolution of electronic data transfer. In the first stage I would distribute a report providing an overview of the data set. I would then tell everyone that received a copy of the report that the data were available in digital form, typically 9-track tapes. (How’s that for convenient!) The next step up the evolutionary ladder was to include an IBM-compatible floppy disk right in the report itself. The disks were cheap and easy to duplicate, so it didn’t matter that some got the data who didn’t really want it. There still was a problem with these approaches. Inevitably, several years would pass and someone would pop up and ask for a copy of the data. Unless I stockpiled a sufficient number of the data disks, it was always a chore to dig up the old data to create a new copy. Discovering a mistake in the data, which required the distribution of a corrected data file, was another problem. While the work in sending out one set of disks was acceptable to me, the distribution of corrected disks was a pain.

This led me to the ultimate step in the evolutionary chain, to a higher plane where all is sweet and light; where children and adults play unimpeded by the encumberances of physical reality. I now distribute data via Internet. (Sorry if I got your hopes up a little too high with that lead in.) When I get involved in a new experiment I offer to set up a group FTP site for the program. Notice I said group FTP site, not anonymous. To do this we set up a single account with username and password on one of our systems. We limit this account so it can access only a selected portion of our file system and further limit upload and modification privileges to a single upload directory. As the FTP administrators we set up a beginning directory structure and stock this with our own data sets. The site is then announced to the community, who all share the same username and password to gain access. All accesses are logged so that we can keep track of who is utilizing the data. Finally we encourage everyone to upload useful data to share with others in the community. In this way the program gains a central repository of data of all types.

In each experiment I am involved in I still find that I have to sell the utility of this approach to the community, but each time the sales pitch is easier to make. Some resistance will come from those who don’t want to share all of their data. To this I say, fine, just share what you want. Some resistance comes from those that are afraid that they lose control of their data. To this I say the data are only available to our colleagues in the program and making the data available electronically in no way reduces the responsibility of a data “user” to obtain permission from the data “owner”.

Of course this is not really the ultimate system. The data are cataloged, archived, and easily available, but it is not easy to browse a bunch of ASCII data files. Some of my colleagues at APL have begun using Netscape and the HyperText Markup Language (html) to document their work. I imagine that after my next experiment, we will use these powerful tools to enhance the group databases with easy browsing features allowing our colleagues to peruse the data graphically to select just what they need.

Independent of how you choose to distribute your data after an experiment, it is of the utmost importance to also distribute a description of the data. I cannot tell you how many times I have gotten data from someone, only to find that I had to decipher the contents as if I were some cryptographer working to break an enemy code. Every set of files should be accompanied by a README file, containing a complete description of the file format (a few example lines can be especially useful), the units of the values (including time), a description of any processing that was performed on the data within the file, and any other information that would be useful in understanding and interpreting the data. It is most important for the description to be complete. While I have argued strongly for the use of universal time for all
oceanographic data sets, not everyone agrees and so you should always specify the time zone utilized for your measurements. Further details should also be included. For example, if the files contain averaged wind speed and direction, you should note whether you used the meteorological convention for measuring wind direction (the preferred choice where 0° indicates a wind blowing from the North, toward the South) and even the method used to average the winds. Many students are surprised to learn that there is no standard method for averaging wind speed and directions, and thus the details of the processing methods used are important.

(The process of averaging geophysical vector quantities is not as straightforward as one might think. Take wind speed as an example. The mathematically obvious solution is to perform a pure vector average, where the average is the vector sum of all the measurements divided by the number of measurements. For wind speeds, this would represent the mean distance that a parcel of air would have traveled in unit time. If in fact, you were attempting to compute the motions of a balloon, then this would be the appropriate measure. In contrast, what if you were attempting to compute the depth of the mixed layer induced by the wind AND the data showed that the wind had been from the North for an hour at 10 m/s and then from South for an hour at 10 m/s. The vector averaged wind of 0 m/s would be clearly inappropriate for this analysis. In this case a better average would be obtained by averaging the wind speed and direction as separate scalar quantities. These two examples show that the appropriateness of methods used to perform vector averaging depends on the use of the averages. Thus, whatever method is used should be specified when distributing data.)

The message here is simple. A supervisor of mine once told me that if you didn’t publish your work, that you might as well not have done it. I now think if you don’t make the effort to distribute data to your colleagues, that you might as well not have acquired it. And by distribute, I mean in a form that others can actually understand and use. The modern tools of the information age make the distribution and archiving of data simple and painless, so you have no excuse to do otherwise.

**Data Acquisition and Analysis Checklist**

|   | Design for necessary timing, rely on automatic GPS clocks when possible. Beware of crystal clock drift |
|   | Make a backup plan and stick with it |
|   | Analyze data on board, if possible, to assure that systems are working and to guide the conduct of the experiment |
|   | Keep up with cruise logs as a way of producing a cruise report soon after the end of the experiment |
|   | Analyze and distribute key data as quickly as possible |
|   | Distribute data in a form useful to other investigators |
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As I have said before, at-sea work is a collaborative affair. No one does oceanographic measurements alone. In fact, the success of your work likely resides as much in the hands of others as in your own. Your relationships with the other people on board the research vessel – the crew, the technicians and the other scientists – are extremely important. Good relationships can lead to help when you need it, and can help insure a pleasant cruise. Bad relationships can ruin the cruise emotionally and scientifically. The golden rule here is to treat others with respect and professionalism.

Originally this chapter was to be entitled "Personnel", but I changed it for several reasons. Personnel is a rather formal management concept, which I think tends to dehumanize people. As an illustration of modern management thinking, within my laboratory the personnel department has been renamed the “Human Resources Department”. To my mind, this was an asinine step backwards, and the people responsible for this nomenclature should have been summarily fired. People are more than just resources to be utilized. On board a cruise, you won’t be so much managing personnel, as you will be interacting and working with people. Thus, to emphasize the more personal nature of work at sea, I’ve renamed this chapter.

Crew Relations

I begin this chapter with a brief discussion of crew relations because although they are critical to any cruise’s success, they are usually the most neglected and abused individuals on the ship. I have seen all too many scientists take the attitude that the crew’s job is to do exactly what they are told, nothing more and nothing less. This attitude is not one of collaboration or cooperation, but one of power and superiority. After all, we are the mighty scientists. We are the ones bringing in the money to pay for the cruise, and the crew are just the hired hands brought along to do our bidding.

I cannot imagine a more horrible management technique. To see exactly how bad this is, let’s turn the tables around for a moment. Suppose a sponsor came to you and offered you just enough research money to support your work. Suppose further, that in order to get this money you had to agree to the sponsor’s exact specifications of the research to perform and the methodology to be used. To make matters worse, suppose the sponsor decided that they would move into your office and lab to direct your work and make sure that everything was done properly. Finally, the sponsor monitored your work as you did it; complained loudly if you made any mistakes; and even brought along fellow sponsors, both young and old, to help guide your progress. I know I wouldn’t put up with such crap for a minute; I doubt if any self-respecting scientist would. Needless to say, this is basically what we do to the crews on our research vessels every day.

I was on a UNOLS vessel once where the crew initially refused to do anything more than supply a crane operator to deploy and recover buoys. When I asked for more support, such as a deck officer to control the whole operation, I was informed that the crew no longer performed this service. I explained to the crane operator that we had a bunch of novice oceanographers on the cruise and that the lowest member of the crew was likely to know ten times more than any of us did about deployment. He agreed with my assessment, but reiterated the crew’s refusal to help. As it turned out, the crew had been berated and criticized for allegedly mishandling instruments on some previous cruises. The crew felt that these criticisms were unjust and had decided to just let all future scientists fend for themselves.
After several days of pleading they finally relented and gave us a hand with the more difficult operations.

The sort of crew abuse that led to their unwillingness to lend a hand is all too common. It comes from scientists that don’t understand the difficulties of working at sea. It comes from scientists that don’t have the first clue as to how to work and get along with other people. And it comes from scientists that care more about their work than about anyone or anything else.

The Crew’s Home

Understanding a little of the crew’s psychology will help you deal with them. First, the ship is for all intents and purposes the crew’s home and you are their guests. The crew spends a lot of time on “their” ship and they do think of it as their home. I can easily understand their feelings as I had similar feelings upon my return from my first two-week cruise. We were busy packing equipment for our offload when the next batch of scientists started moving their equipment and personal effects on board. I couldn’t believe how rude these people were coming on to my ship, moving equipment into my lab, and even putting a duffel bag into my state room. It took me a while to recall that I was only a graduate student who had spent all of two weeks at sea on this ship. I had little right to think of anything on this ship as mine. It was only upon reflection that I realized how the crew must feel each time a new group of scientists come on board.

So when you begin an onload, remember to treat the crew with respect. Act as if you are guest coming into their home for the first time. Yes, they are being paid to assist you, but the tone you set during onload may well affect how the crew think of you during the entire cruise.

Privacy

Once the ship has set sail, you must respect the privacy of the crew and everyone else on board. Ships are small confined spaces and most people need some time and space to themselves. You should especially be aware of creating noise and disturbances around the crew’s sleeping quarters. Modern research vessels are operated 24 hours a day, so there is always some portion of the crew resting or sleeping. Try to keep the noise in adjacent labs to a minimum and be aware that slamming hatches are particularly bothersome. Due to the confined spaces, most ship’s laundries are near someone’s bunk, so find out if there are scheduled hours for use of the machines.

Mess Etiquette

Another place that scientists get themselves into trouble is with respect to feeding schedules and seating arrangements. The cooks on board usually have a very full workday providing three or four meals a day for the scientific party and crew. For this reason, the meal schedule is usually quite rigid on board ship. If you are real nice to the cooks and have a real legitimate need to work through a meal, they may be able to bend the rules; but don’t abuse the privilege.

Seating in most messes is insufficient to seat everyone at the same time. Thus the rule is to eat and leave, freeing up your seat for someone else. Even if you are the last to eat at a given meal, don’t linger after you are done. The cooks need to finish cleaning up before starting the next meal and it will drive them crazy if you hold them up or even if you’re just sitting around doing nothing.
The seating in the mess is often segregated with the crew sitting at their own tables or sometimes in a separate mess. If this is the case, respect the crew’s wishes and stick to sitting at the tables for the scientists. I always ask a crew member where the scientists should sit and where the Captain sits when I first arrive on a new ship. Believe me when I say that you don’t want to begin a cruise by taking the Captain’s place at a meal.

And while it usually doesn’t bother the crew, I’ll include one more point about mess etiquette here. Namely, the strict adherence to a watch schedule would mean that the scientists on a particular watch would regularly miss certain meals. I agreed with one friend’s comment that he particularly liked being on the 4-8 watch, so he could see the sunrise and sunset. The major problem with standing this watch is the conflict with breakfast and dinner, which happen to be two of my three favorite meals a day. The solution is for the conflicted watch to eat in shifts, or for someone in another watch to fill in while the nominal watch stander grabs a quick bite. For this reason, those standing watch are usually given priority in the mess. Just be aware that these conflicts exist and be prepared to help all involved work around the problem. Remember, that it may be you that needs some help on the next cruise.

These points about meals are quite important. Meals are a major social event on board ship for the crew, although I doubt if they would think of it in quite those terms. This is a time for them to relax and to catch up with other members of the crew who’s jobs may keep them far apart during their watch. The last thing that most crew want to hear are the intense and often incomprehensible ramblings of the scientists.

If you have the privilege of serving on a foreign ship with an open bar, don’t assume the alcohol is free! The first time I was on board a Scottish ship, they crew invited me for a drink. After I had finished my work that day, I went to the lounge to find several of the officers relaxing. I asked the first mate how the bar tabs were maintained, inquiring whether I should pay cash or just run up a tab that I could pay off later. His surprise at the question was evident as he explained that I could just pay as I go. I then offered to buy a round of drinks for the few officers in the room. I had a few beers, a pleasant conversation, and thought little more of the incident. Several days later, one of the officers mentioned to me that all of the officers had been impressed with my behavior. He claimed that I was the first scientist that had not just helped himself to the bar, thinking that if it was not under lock and key, it must be free! Scientists had abused the system so frequently that the crew had instituted a special policy allowing new scientists to drink for free the first day. On the second day someone would then sit them down and explain the rules of the bar. The officers were amazed that I would ask about paying before I got a drink and even more amazed that I would offer to buy a round, even though the total cost was just a few dollars. Small things like this create a sense of friendship and mutual respect that can really help out on a cruise.

Including the Crew

Another way that you can work with the crew as a team is to fill them in about your scientific objectives, techniques, equipment, etc. While many crew members won’t be interested, you may be surprised at how many are interested and who want to learn. I am not suggesting that you hold mandatory seminars for the crew, but when someone asks a question, take the time to answer it. By encouraging interest in your work and equipment you will be giving the crew more of a stake in the success of your work. I know explaining things takes some time and energy, but your efforts will be rewarded by a crew that is more attentive to your needs and more careful with your equipment.

I once had to make several flights on a U. S. Navy P3 aircraft in support of a small remote sensing experiment. After the orders had been transmitted to the squadron head, I
phoned him and offered to arrive a few hours before the first flight to give a short presentation on what we were doing in the experiment as a whole and how their P3 flights fit into the grand scheme. He was surprised when I suggested that in addition to the officers, the crew be allowed, but not required, to attend. He readily agreed and I ended up giving a half hour briefing on the promises and problems of remote sensing to a packed briefing room. The officers were grateful for the presentation, but what struck me most was that several enlisted men approached me during the flights and thanked me for including them in the briefing. One told me that they had flown missions with other scientists and that I was the first that had taken the time to explain to them the purpose of the research.

Coming down to a more typical altitude for oceanographers, it is important to remember that just about every crew member will have more experience at deck operations than you will. Consult with them regarding your plans for deck operations. Ask their opinion about things and listen to their answers. Act as if they are a member of the team, because they are. When you are discussing your plans with the crew, be sure to seek out the opinions of the deck hands and not just the officers. After all, the deck hands will actually be the ones handling the equipment, not the captain!

My first time in Scotland, I was nervous about the deployment of our wave spar. It is not particularly heavy, but it is awkward and is best deployed in a rather particular way. I talked over the plans for deployment with the bridge crew, but I was aware that the young deck officer who would be in charge of the operation was new to the ship and the maritime service. I was concerned about this, so I sought out the ship’s Bos’n, who would actually do the work. That evening, over a couple of beers, I told him about our buoy, about the possible difficulties in putting it into the water and my concerns about how it would go. The Bos’n assured me that he could deploy the buoy without so much as a scratch and spent several minutes going over the procedures with me. The next day, true to the Bos’n’s word, the deployment went like clockwork. While the young officer was ill-prepared, the Bos’n had thought the whole operation through rather carefully and did a fine job of directing his crew. I think if I had just left it in the hands of the deck officer, I might have ended up with two short spars instead of one long one.

Sociology of Scientists and Crew

After substantially finishing this section, I came across a fascinating article by H. Russell Bernard and Peter Killworth that appeared in the April 1976 issue of the Marine Technology Society Journal entitled, “Scientists and Mariners at Sea.” Dr. Bernard is a sociologist who teamed up with Dr. Killworth, a well known theoretical oceanographer, to study the interactions of scientists and crew at sea. Stories about at-sea strife, friction, and even sabotage, led them to participate in several cruises in order to evaluate the relationships between the scientists and the crew. The picture that they present is in nearly complete agreement with the one I have put forward here in this section.

They do make a strong case that some of the friction present between scientists and crew are due to the differing social classes of the two groups. They point out that on land, scientists and crew would rarely be the types to interact together. Their view is that a certain amount of stress is natural in these relationships. Still, the stories that they relate indicate that in most cases, strife could have been eliminated or at least reduced if the scientific party had treated the crew with a modicum of respect. Their article is well worth reading and I recommend it highly.
Adjustments

This section is called adjustments because it addresses your own behavior on board ship. While the rest of this chapter addresses your relations with others at sea, there are some broad adjustments that you'll have to make in your own habits to successfully work at sea. These aren't hard, but they do take some getting used to.

“Water, water, everywhere, nor any drop to drink,” was a famous line from *The Rime of Ancient Mariner* by Samuel Coleridge. Well that’s what it would be like on ships without water distillers, those wonders of modern engineering which make fresh water the old fashioned way, one drop at a time. On most modern research vessels the distillers can produce plenty of water. On other vessels the distillers are smaller and less productive, making water a somewhat precious commodity. In either case, if the distillers break, then serious problems can occur including water rationing and the premature end of an experiment. This information is but a long-winded introduction into the wonderful world of military showers.

Military showers are the preferred mode of bathing on most vessels that I have been on. The idea is simple. You begin by turning on the shower just long enough to wet yourself down. With the shower off, you then lather up and wash. Finally you turn the shower back on just long enough to rinse off. Think of it as a real shower just without the water in the middle. Military showers are required on many ships, so ask before you first wash, and keep the water usage down to a minimum.

In an earlier section, I suggested that your job was to do whatever needed to be done. Well on board ship, that will include cleaning your own quarters. You’ll usually be sharing quarters with other people, so you can’t just let a mess pile up. Clean sheets are typically issued once a week, usually by the ship’s steward or cook. On one cruise I was on, the scientists were even required to take turns cleaning the head.

At the end of each cruise it will be your responsibility to strip all of the laundry from your bunk and return it to the steward. You must clean your room and space, leaving it in the same or better condition than you found it. These are not unreasonable requirements, but please don’t tell my wife that I clean at sea, because she could start expecting the same at home.

I told a story above about drinking beer with the crew of a foreign ship in the context of crew relations. If you do find yourself on a foreign vessel, don’t abuse the privilege. If you are on a U. S. vessel though, don’t even take it along, as alcohol is prohibited on all U. S. research vessels I have ever been on. While I enjoy a cold beer at the end of a hard day as much as the next guy (maybe even more), it really can cause a lot of problems and so it has been banned. Although I shouldn’t have to say it, illegal drugs are even more strictly prohibited. If you are caught with drugs on a research vessel you will in all likelihood be prosecuted and your sea-going career will certainly be over. U. S. laws allow for the confiscation of any vessel where drugs are found, including research vessels. Believe it or not, this law has been applied, at least temporarily, depriving one major oceanographic institution of their research vessel for some period of time. If you for one moment think that your value to your organization offsets the possible risk of losing a multi-million dollar research vessel, think again. Drugs aren’t worth it. Just don’t do it.

Leadership

Once you start going to sea you may aspire to a leadership role, either within your research team, or of the entire scientific crew. The best scientists naturally progress towards
the responsibilities of leadership. It is a natural progression because you can only truly control your own work when you are running things. There is also an element of ego involved in wanting to be a leader. Everyone that has been on a few cruises has at one time or another felt that they could do a better job than the chief scientist. Well I have been a team leader numerous times and have acted as chief scientist on a major cruise, and the first thing I discovered was that it’s not easy. Everyone depends on you, looking to you to make all of the decisions. You’ll also find that surprisingly you have less freedom to control your work then you did before. This is because you are now responsible for everyone else’s work as well as your own. True leadership is very demanding.

The topic of leadership, how to be a good leader, and what pitfalls to avoid, is a massive subject. I can’t provide you with all of the answers. Each time I act as team or a cruise leader I become more aware of my own limitations in such roles. I can comment though about the common traits I have observed in others that I consider to be good leaders. I can also warn you of some of the problems that I encounter when I have acted as leader, problems that you should try to avoid.

First and foremost I think leaders need to have the respect of the team. In this context there are two elements to respect: scientific and personal. Scientific respect arises from the team’s recognition of the leader’s command of the overall problems to be studied on the cruise. To gain scientific leadership you must know your field, you must know your instruments and techniques, and you should attempt to know the work of the others on your team. A cruise leader has the responsibility to learn as much about the other investigators instruments and techniques as possible. Only by knowing the other investigators capabilities and interests can you truly evaluate the competing demands that occur for ship resources and time.

To gain personal respect from people requires that you set a good example for the others, and that you treat everyone as valued contributors to the team. I personally prefer not to act as a strict leader but more as a facilitator. This helps insure the equality of everyone on the team, and makes everyone feel like a contributor. I have found that most, but not all, people respond best to this form of leadership. (I’ll admit that I’m still trying to figure out what, beyond strict management, to do with those that don’t respond well to responsibility.)

The best leaders I have encountered set a good example for the rest of the team. They work hard, are level headed, and are focused on the success of the cruise. I have been in the field with people who are lazy. Teams quickly lose respect for someone who does not pull their own weight. That doesn’t mean that the leader needs to do every job on the ship, but it does mean that the leader should be visibly working hard to insure the success of the cruise. I have been in the field with people who are depressed, excitable, and even manic. Unevenness in a leader tends to destroy the morale of the team because of the inherent irrationality and fear that it causes. People don’t work well if they are afraid. Finally, I think a leader needs to appear focused on the success of the cruise. The best time to project such leadership is when things go wrong. If you chose to spend your time trying to assess blame then the members of the team will get the message that the results are not the most important thing. Focusing on the solution sends the message that the results are what are important.

I personally have difficulty with the delegation of responsibility. Most of the time I have no problem supervising a group of well-trained and motivated individuals. Delegation is easy in these situations because I know that the job will nearly always be done right. Still, I check on others work, just as I encourage others to check on mine. I find that a constant dialog between all members of the team, involvement of everyone in decisions and having each job checked by another, builds team confidence and helps cut down on costly errors. I may be the
senior member of a cruise, but I have been saved from errors by the most junior members of my team more often than I care to recall.

My problems in delegating responsibility instead stems from those cases where a team member consistently has difficulty in carrying out their assigned tasks. I understand that in these types of situations standard management theory suggests the progressive application of increasingly intrusive management. For example, some experts suggest that you want to progressively make each assigned task simpler while increasing the amount of supervision, until the individual can satisfactorily perform the assigned tasks. Additional training, or teaming the individual with a more capable colleague are also suggested remedies. All of this theory may be fine on land, but with the high costs of ship time I have great difficulty with people who cannot perform their jobs. My typical response to such a situation is to just bypass the person at sea, and to not sail with them again in the future. I have never been satisfied with this solution, but it is the best I have been able to devise. I hope you can devise a better strategy in your work.

I suggested above that a good leader will include others in the decision making process. Nevertheless I’ll caution you that a leader must be decisive. A good leader encourages input, weighs the options and then makes a decision. Leaders that can’t make decisions are not truly leading.

I recall the planning of one experiment in particular involving a colleague who is, shall we say, decision impaired. I had suggested to him a minor addition to the experiment which was essentially zero cost, but that might yield some interesting results. He asked for a memo detailing my suggestion, which I didn’t mind writing. He then had copies of the memo sent to eight separate colleagues at our lab, all of whom he invited to a meeting to discuss my suggestion. When we got to the meeting it became apparent that no one had actually read my memo, so I had to give a presentation on my proposal. Afterwards, the discussion went on for an hour. At the end of the hour, despite the fact that no one had any objections to my proposal, and everyone agreed it involved zero cost and low risk, the experiment leader decided it should be evaluated in more detail by a subcommittee, that was to make a written recommendation to him regarding my proposal. To me the whole exercise wasted several man-days of effort in making a decision that was essentially a no-brainer. In the end, the experiment leader gained a written recommendation that served to clear him if anything went wrong, but at the cost of my respect for him. I’ll leave it to you to decide if such a tradeoff is worth making.

In those cases where I am a member of a team, I always remember that the team leader gets to make the decision. As a member I will sometimes argue forcibly for my beliefs and views, but unless it is a matter of safety, I will in the end respect and support the decision of the leader. This is an important lesson to take to heart when the chief scientist on the cruise makes a decision against your research interests. Just remember that in doing so they are trying to balance the competing interests of others and that in the end someone has to make these decisions.

The final key to leadership is communications with others. The rest of the team, and likely the crew, need to know what you expect of them at all times. They also need to know what is going on with the cruise as a whole and in particular with the team’s work. The team needs to know what decisions are being made and why. This takes more time than you can imagine, but it is a necessity. Chief scientists that stay in their cabin and interact with just the captain and one or two other scientists reduce the efficiency of the entire team. Team leaders need to communicate the rest of the team on a continuing basis.
On one international cruise where I was acting as the U. S. chief scientist I was so busy that I started neglecting to fully brief my colleagues on exactly what was happening. Several of my colleagues got angry with me, accusing me of purposely withholding information from them to cut them out of the decision making process. I didn’t view my error in quite so dramatic terms, but in the information vacuum that I had created, these colleagues were left to imagine and create some framework for my behavior. The simpler explanation of my being too busy was rejected in favor of a more active and belligerent explanation. After all, they reasoned, what is more important on a cruise than to provide the scientists with sufficient information to do their work? I now realize that they were right. A leader must communicate with his team.

Finally, on this topic of leadership I’ll say a few confessional words about our expectations of others. It is a fact that we judge the behavior of others, not by some explicit set of rules, but against our own expectations. Personally, my expectations of others, varies widely from a rather high standard for those who I work with regularly to a lower standard for people I don’t know. The fact that others are judged by our own standards and the fact that our standards and expectations differ from individual to individual is often overlooked in this day of rationalism and scientific certainty. I think it especially easy for scientists to fall into the trap of thinking that everyone should behave as they do. I know it has been easy for me to fall into this trap myself.

Here I am writing a book about the conduct of oceanographic experiments wherein I express an opinion about just about every aspect of working at sea. As a theoretician might study the Navier-Stokes equations, I have studied what makes for a successful oceanographic experiment. Although some will think it an immodest comment, I am reasonably good at what I do. Unfortunately, from this rather arrogant viewpoint I have sometimes made the mistake in assuming that all of my close colleagues uphold the same expectations of themselves as I do. Don’t get me wrong, I think the people I work with on a day to day basis are some of the best researchers I know. It is just that at times my expectations for their behavior have been unrealistically high. For example, I have caused unnecessary friction by assuming that a colleague, who is responsible for an agreed-upon set of instruments, has taken the time to learn about someone else’s instruments just because he’ll be at sea with them. When I found out differently, I was upset and an argument ensued. In retrospect I have come to understand that this wasn’t my colleague’s shortcoming, but mine.

As you gain in experience, you must keep in mind that the experiences of others will necessarily differ from yours. I think it best to keep high expectations for your self, but to be realistic about what to expect from others. It is far better to be occasionally surprised by someone exceeding your expectations than it is to be continually disappointed by others failing to meet your expectations.

Other Scientists

Because of the expense of ship time, you will typically be working on a cruise with other groups of scientists. This means that you have to find ways to cooperate with these other scientists. This is important not only to insure that you get your data opportunities on a cruise, but may also be important for the post-test collaborations that may result. In the end, every scientist is judged by their peers for the work they do. These judgments are not cold and dispassionate, but are heavily influenced by how well you get along with others.

Let’s face it: many good scientists have big egos. I sometimes think it is the price that we pay for being good at what we do. At the same time, many scientists are competitive and some are downright antisocial. (I just love broad generalities, don’t you.) There are times
when putting a group of scientists into the confined space of a ship for several weeks does not seem like the smartest of ideas.

If you find yourself on a cruise with a bunch of egos, it is important to be aware of the possible difficulties, and to make the best of each situation. I have found that if you treat people with respect, they will respect you, even when they disagree with you. When the chief scientist makes a decision that is contrary to my point of view, I understand that it is nothing personal, and I move on. I try to be careful about not denigrating other scientist’s work on board a ship, even if I think they’re dumber than a stump. I have not always been so careful and the results can be disastrous. Remember, there are no secrets on a ship, so if you put someone down, everyone will know it.

On one cruise, I went to sea with a scientist who didn’t understand his instrument, had not properly checked it out, who tried to take credit for other’s work, and who knew virtually nothing about oceanography. This guy was, and still is, an absolute idiot. One day on board ship, in an incident that to this day I regret, I blew up and told him exactly what I thought of him. In this case, everyone else on board happened to agree with me, so there were almost no visible repercussions. Still, I have never felt that what I did was right. It is non-professional to allow personal feelings to interfere with your work. I can think of almost no circumstances where chewing out someone at sea will actually do anything to further the objectives of the cruise. It will usually do just the opposite and create friction and strains within the team and crew. Instead of blowing up at this person at sea, I should have been more patient. I should have tried to make the best of the situation by helping out wherever I could, and then, once we had gotten back to dry land, I could have yelled at him. After all, while I never again have to go to sea with this scientist, and I use the term loosely, I did have to finish the cruise with him. Try not to make the same mistake that I did.

Another thing that I do to aid my relationship with my colleagues on ship is to try to help them with their work whenever possible. My rule is to get my work done first, but if I have prepared well then there is usually plenty of free time. If I spend this time helping others with their equipment, their deployments, their problems, then everyone benefits. The sponsor is happy because the experiment may be slightly more successful. The scientist that I help is grateful. And I have spent my time productively and have usually learned more in the process than if I had watched videos in the lounge. I like going to sea with people that are willing to help others, and have a strong aversion to working with those that are only interested in their own work. This is only natural. You have the power to decide which type of scientist you will be. Remember, though to get your own work done first.

I have just presented my plea for cooperation on cruises. Now I’ll present a little warning. At sea, you will often have to rely on data products from the ship or other scientists. On a recent cruise for example, one group made wave measurements, one group atmospheric measurements, and I recorded currents and navigation data. In this case, I had to rely on the other groups to do their jobs in order to obtain data critical for my research. On this particular cruise things went well, but my advice is to rely on others with caution. There are too many scientists in the world that place undue faith in the accuracy of their instruments. There are too many ways that measurements can go wrong for me to trust others blindly. After all, I typically don’t trust my own measurements until I have worked with them for some period of time, so why I should I trust someone else’s measurements, especially if that person is not as careful as me.

Matters are even worse if you must rely on measurements made from the ship’s instruments. Newcomers may find this hard to believe, but even on our best research vessels, it is hard to find any instruments that can be trusted. On a recent UNOLS cruise, I discovered a several minute error in the ship’s navigation data when compared with data I had recorded.
It turned out to be a software bug in the ship’s data acquisition system that added exactly 3, 4, or 5 minutes to the recorded time; the offset being dependent on some odd confluence of conditions which occurred at the system boot time.

On a German research platform I was once on, I went to read the wind speed and direction from the official platform wind display. A few minutes later I went outside and realized that the wind was blowing from the North but that the display had indicated a wind from the South (180°). After some investigating we discovered that the platform’s meteorological system averaged the direction data before it was recorded and that the average of an anemometer which is swinging between 355° and 5° is close to 180°. Amazingly the investigators responsible for this system told me that they had an algorithm for removing the errors introduced by this averaging. It has been several years since the end of that experiment and I am still awaiting the details of this miraculous algorithm.

I could go on and on and on. Ships’ instruments are rarely calibrated and are rarely to be believed. You may in fact wonder, if things are so bad, what are you to do. My best advice is to double check the people and instruments that you are relying on. I sometimes annoy other scientists with my persistent questions about calibrations, timing, instrument biases, and data recording and analysis algorithms. But it is only by asking lots of questions and carefully evaluating the responses that I can come to a decision about whether to trust a particular data stream. In deciding to trust a data stream I am choosing to trust the instrument, its recording system, and typically the analysis of the scientist responsible for that instrument. I have to be convinced that all is in order before I use someone else’s data.

One solution is to acquire duplicate data. This is usually a good idea in any case, because the redundancy acts as a check on each system. Still this is not always practical. In these cases, pick the people you work with carefully, and ask lots of questions.

**Women at Sea**

I just know that I’m going to get into some problems with feminists over this section, but there are some things that I believe need to be said. First let me clearly state that women at sea are not a problem. While women oceanographers are unfortunately rare in our society, I have never been to sea with a woman who has acted in any way but professionally.

In my mind the problem is not the women, but it is the men. More specifically, the problem is with a very few men that see women at sea as more than just professional colleagues. (Now I’m probably in trouble with members of the men’s movement.) This shouldn’t be a problem, but it is, and so I am writing this section as a friendly warning to those men who view the opportunity of working with women on board a ship in something other than a professional way.

There are two distinct types of problem men at sea, men that go looking for trouble and those that don’t, but find it anyway. I have worked with a few lecherous, Neanderthal oceanographers in my days, who feel that it is acceptable to hit upon whatever women they might come across. Other than avoidance or prosecution, I know of no way to discourage such men from their onerous behavior. Luckily, I think such men are becoming rarer.

The larger problem are those otherwise good men that get themselves entangled in shipboard romances. I realize that a shipboard romance requires two people, but it has been my observation that men are usually the aggressors in these situations. It is interesting to note that the remoteness and confinement of a ship cruise where you are forced to work side by side with members of the opposite sex can be somewhat intoxicating. The romantic
aspects of sea cruises, which I have already noted, tend to heighten some people’s attraction to members of the opposite sex. Lest you believe that I am exaggerating the psychological significance of these effects, let me point out that the spouses of oceanographers at Woods Hole once put out a booklet on shipboard romances. This booklet was placed in each cabin of the WHOI research vessels to remind the oceanographers of the traps that awaited them at sea and the possible repercussions of illicit romances to their lives on land. Another indication of the problem can be found in *A Manual for Seagoing Scientists*, a brief introduction to working at sea that arose from a special Women on Ships committee at Scripps. Over two pages of this 25-page manual are devoted to a discussion of at-sea interpersonal relations and sexual harassment.

I won’t get into a discussion of the morality of shipboard romances. That I think is best left to each individual’s conscience. Besides which, unless one or both of the individuals are married, most people today have no moral problem in two consenting single adults entering into a relationship. Despite the laxness of post-industrial sexual mores (I’m not sure quite what that means, but it definitely sounds cool), relationships on board ship are not professional and inevitably lead to problems.

First, I have seen adult men quarrel at sea over the favor of a woman. This is ridiculous. We go to sea to work, and in fact large sums of money are invested in that work. Working at sea is difficult enough without interjecting romantic conflicts and competitions into the mix. Even when men don’t overtly quarrel there is a certain competitiveness in many men that is enhanced when someone else is involved in a romantic relationship. You’ll find people commenting about the relationship, telling jokes, and denigrating the individuals that are romantically involved. This hurts team work and the cohesion of the group that is so vital for success at sea.

Second, people who are infatuated will often not work at their full potential. I have seen cases where scientists overslept their shifts because of their late night activities with members of the opposite sex. Again, in my view we were put on the ship to work, not to fool around. I admit to being rather spartan in my views but I am against anything that decreases the efficiency of the cruise.

Third, think about how shipboard romances affect the ship’s crew. From experience, I can tell you that the crew doesn’t think much of the scientists involved. The crew on a research vessel works hard to support the scientists. When they see two people carrying on a relationship they come to the conclusion that the science is not the most important thing to those people. And why shouldn’t they think that?

Finally, shipboard romances are simply not professional. Over the years I have been amazed at the stories that I hear about people fooling around on sea cruises, cheating on their spouses, and lying to their colleagues to cover it up. There are no secrets on a ship. Furthermore these stories never seem to die. Humans as a whole are a gossipy bunch (for example, see most of the stories in this book!). Once these stories begin, they have a life of their own. It seems to me that a married man who fools around on a ship need not worry too much about his wife finding out, but should instead be worrying about what his colleagues think of him.

If after reading this section, you still desire a romance at sea, pay for a trip on a cruise ship. Research vessels should not be the Love Boat.
Chapter 8. Other Resources

So, you've finished the book, absorbed every bit of wisdom that was offered, and now you ask “Where do I go from here?” The easiest advice is to just go to sea and do it. I can’t predict how successful your work at sea will be, but I can guarantee that the experience will be different, at least in some aspects, than you currently imagine, that something will not go as planned on your cruise, and that you’ll come away with a new respect for the people who do this for a living.

As I have tried to stress in this book, you should continue your attempts to learn. There are many other resources that you can use to better prepare yourself for working at sea. This chapter lists a few of these resources that you may find useful.

Of the books and articles I have referenced, I highly recommend Anatomy of an Expedition by H. W. Menard. The book may be a little difficult to find, but it is well worth the effort. Menard’s book is the earliest work I have seen that tries to describe the work of a wet-deck oceanographer. I can also highly recommend the article by Bernard and Killworth entitled “Scientists and Mariners at Sea”. I think their pioneering work on the sociology of scientists and crew should be required reading.

There are several other references which are are valuable for particular topics that I have discussed. For ship’s safety I refer the reader to the excellent RVOC Safety Training Manual – Crew Supplement available from UNOLS, and the Vessel Safety Manual published by the North Pacific Fishing Vessel Owners’ Association. Both books are extremely well produced volumes filled with useful information on the practical problems of working at sea. Both volumes discuss such varied topics as basic seamanship, watchkeeping, rigging, medical emergencies, and fire fighting.

Knight’s Modern Seamanship and Piloting, Seamanship and Small Boat Handling by Chapman (no relation) are both standard references in the field of seamanship.

In addition to your local library, there is a growing amount of useful information available on the Internet’s World Wide Web. The WWW is so dynamic that any attempt to provide a list of useful addresses is fraught with difficulty. While it is likely that a number of the addresses I list below are out-of-date by the time you read this, the list should still serve as a jumping off point to the wide variety of information that is available in cyberspace. Alternatively you can start at my group’s home web site that contains these and other useful links: http://fermi.jhuapl.edu/

Web sites listing links to oceanography related sites

http://hydra.tamu.edu/~baum/oceanography.html
Very complete listing of Oceanography resources on the web. Includes an oceanography glossary, listing of textbooks, software resources, etc.
http://www.mth.uea.ac.uk/ocean/oceanography.html
WWW Virtual Library: Oceanography - Full of oceanography links
http://scilib.ucsd.edu/sio/inst/
Scripps listing of oceanographic institutions
http://www.unesco.org/ioc/infser/OCPILOT.HTML
UNESCO listing of international oceanographic institutions
http://www.yahoo.com/Science/Earth_Sciences/Oceanography/Institutes/
Yahoo's listing of oceanographic institutions
http://www.esdim.noaa.gov/ocean_page.html
NOAA listing of Oceanography Resources
http://www.ngdc.noaa.gov/paleo/aslo/hotlist.html
ASLO listing of websites in earth sciences

Web sites listing links to ocean engineering / maritime related sites

http://www.ish.dtu.dk/wwwvl_naoe/home.html
   The WWW Virtual Library: Naval Architecture & Ocean Engineering
http://www.mainelink.net/~drwebb/maritime.html
http://pacifier.com/~rboggs/
http://www.efn.org/~jkohnen/boatlink.html

UNOLS / Ship Information

http://www.gso.uri.edu/unols/unols.html
   UNOLS Home page
http://diu.cms.udel.edu/ships/ship_menu.html
   Research Ship Information and Cruise Schedules

The best of the R/V home pages which include useful Cruise Planning Manuals

http://www.udel.edu/marine_operations/
   R/V Cape Henlopen home page
http://www-ocean.tamu.edu/GeneralInformation/gyre.html
   R/V Gyre home page
http://www.oce.orst.edu/Wecoma/WecomaHome.html
   R/V Wecoma home page (includes past Cruise Plans)
http://sio.ucsd.edu/supp_groups/shipsked/
   Many Scripps vessels include useful ship handbooks

Other useful sites

ftp://sundae.triumf.ca/pub/peter/index.html
   NMEA-0183 (a data protocol used in marine navigation instruments) and GPS information
   Interesting article about problems of extended separation from one's family (written for Antarctic researchers)
http://www.argosinc.com
   The ARGOS system
References


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Appendix A. Excerpts from the APL Safety Manual

This document is an abridged version of an At-Sea Safety Plan originally compiled and written by Mr. Stephen Root for the Submarine Technology Department at JHU/APL. The document has been edited by Dr. Richard Gasparovic who removed some material that is peculiar to APL operations. I have included this as an appendix to provide a good example of an at-sea safety plan. It is full of useful suggestions to make your work at sea more safe and productive. I suggest that you study this material carefully. Feel free to copy this appendix and distribute it to others within your party.

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CHAPTER 2
SAFETY SUPERVISION

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CHAPTER 1
PERSONAL SAFETY

INTRODUCTION

This Safety Plan for At-Sea Operations has been established to provide a standardized and effective set of policies and procedures for personnel involved in planning, directing, or participating in field tests. The primary purpose of the plan is to provide safety education and orientation for scientists, engineers, technicians, and support personnel who, as a part of their work, find themselves performing their duties aboard ship, either pierside or while underway. This plan provides basic information about the hazards of the marine environment, and emphasizes individual responsibilities in working and relaxing safely while at sea. Test Conductors will supplement the information found herein with operational and safety procedures specific to each test.
PREPARING FOR SEA

Safety at sea begins with adequate preparation ashore. In addition to finishing your technical tasks prior to heading for the field, there are a few things you should do to make the cruise safe and productive.

• Get a physical examination. Field test participants should complete a physical examination within 12 months of commencing the test. This checkup should include the dentist.

• Attend the pretest operations briefing. As part of the test preparation process, the Test Conductor will provide a briefing on the upcoming evolution covering operations, administration, and logistics. The Test Conductor will also address any special safety precautions or hazards peculiar to the test during this briefing.

• Pack clothing appropriate for the environments on board the ship and ashore at the embarkation/debarkation site. For work in winter weather, wear warm, lightweight clothing in layers, so you can remove some if you begin to perspire or need to go inside. Ships are full of hazards from rotating machinery, slippery decks, and high voltage. Choose clothes to minimize your exposure to these dangers.
  - Do not wear neckties or scarves, loose or dangling clothing such as blousy sleeves or baggy trousers, oversize sweaters, or high-heeled shoes.
  - Rubber-soled shoes with non-skid soles are best. If you work on deck, bring an extra pair in case these get wet. If your job involves handling or moving heavy material, wear safety shoes.
  - If you wear jewelry to the ship, take it off and put it in your cabin drawer. Gold is an excellent conductor of electricity, and rings caught on a stanchion or post can easily remove fingers.
  - Save some room for emergency clothing. Pack for the worst situation possible - abandoning ship. Put in a hat or watch cap, long-sleeved shirt and pants, and for a cold climate, a pair of gloves. These items are invaluable in protecting you from sunburn and dehydration should you have to enter the water or a life raft.
  - Pay special attention when you are packing to those items you can’t live without. These include prescription medication (bring enough for the trip plus an additional 25 percent), contact lenses, and eyeglasses (bring an extra pair if you can’t see without them).

BEFORE GETTING UNDERWAY

Once you arrive at the ship and have settled in your living space or stateroom, note the location of the safety equipment near your berthing area and work space. Prior to getting underway, a detailed safety briefing will be given by the Test Conductor. This material will be part of the presail briefing, delineating specific safety procedures for the upcoming underway period.
No later than 48 hours after getting underway, the first in a series of periodic drills will be held to further familiarize everyone with the ship’s emergency procedures. In addition to these evolutions which require your participation, the following exercises will help you become familiar with your surroundings:

- Find two pathways from your berthing and work areas to the main assembly area and the ship’s exterior.

- Locate your life jacket and survival suit stored in your stateroom. Extra life jackets and survival suits should also be available in your work area. Note their location, also.

- Inspect your work space and properly stow all tools and equipment. Likewise, check your berthing area and stow your personal belongings and any work-related equipment (e.g., laptop computers and calculators) that you have brought on board. Ensure that all your cabin furnishings are secured to prevent damage or injury should the ship encounter severe weather or high seas.

- Find the fire extinguishers closest to your living and working spaces and note what classes of fires they are appropriate for. If your work space is protected by a Halon fire extinguishing system, learn how to manually activate it and what the alarm sounds like if it is automatically activated.

- Read the ship’s station bill located in your berthing area; a sample is provided in Figure 1-1. The bill summarizes the emergency signals, mustering procedures, and lifeboat assignments for occupants of each stateroom or berthing area.

- Try on your life jacket and survival suit. Ensure that they fit and all the ties and zippers work. If they are broken or missing, see your Test Conductor for a repair or replacement.

- On rare occasions or in a catastrophic emergency, the ship’s crew, who are normally assigned to launch lifeboats, may not be available. In addition to the lifeboats, the ship carries large inflatable life rafts which can easily be launched by any crewman or passenger. Figure 1-2 shows a sample instruction placard for launching one of these rafts. (For added safety, these rafts are automatically launched and inflated by a hydrostatic or tension switch should they sink with the ship.) In addition to knowing the location of your assigned lifeboat, find out where these inflatable life rafts are stowed.

**UNDERWAY CONDITIONS**

After the ship is underway, the Test Conductor will set and maintain an Operating Condition that reflects the level of risk associated with the local environment, and with the nature of current or scheduled operations. The Operating Condition imposed is determined by agreement between the Test Conductor and the ship’s Captain and is announced to the technical party. The Operating Conditions, as set forth below, regulate access to certain portions of the ship and the extent to which additional safety precautions must be incorporated when working in areas other than laboratory spaces.

**Condition 1** - Condition I is the normal underway operating condition. No areas designated for open access are restricted. Work topside, or on decks exposed to the
weather or seas, may be performed within the guidelines of normal safety precautions. Access to weather decks for work or leisure is unrestricted. Individuals working topside need not be accompanied if their work can be completed safely alone.
R/V AMY CHOUEST - STATION BILL

SIGNALS
FIRE...............................One Continuous blast of the Ship's Whistle and continuous ringing of General Alarm Bells, both sounded for not less than 10 seconds.
ABANDON SHIP ..............7 Short Blasts and 1 Long Blast of the Whistle and the same signal on the General Alarm Bells.
MAN OVERBOARD.........Hail, and pass the word MAN OVERBOARD to the bridge.
DISMISSAL.......................From FIRE AND EMERGENCY stations, 3 Short Blasts on the Whistle and 3 Short Rings on the General Alarm Bells.

WHERE WHISTLE SIGNALS ARE USED FOR HANDLING BOATS & EMERGENCIES
Lower Boats ...........................................................1 Short Blast On Whistle..........................Emergency is Forward
Stop Lowering Boats ..............................................2 Short Blasts on Whistle..........................Emergency is Aft
Dismissal from Boat Stations.................................3 Short Blasts on Whistle.........................Emergency is Below Deck

INSTRUCTIONS
1. Entire crew shall familiarize themselves with the location and duties of their Emergency Stations immediately upon reporting on board.
2. Each crew member shall be provided with an individual supplementary Station Bill Card which must show in detail the specific duties to perform.
3. Entire crew shall be instructed in performance of their special duties and crew on watch will remain on watch on signal for Emergency Drill.
4. Every person participating in the Fire and the Abandon-Ship Drill will be required to wear a life preserver and appropriate clothing. i.e., cap, long sleeve shirt, shoes, and have survival suits in hand.
5. Emergency squad will assemble with equipment immediately upon the Emergency Signal.
6. Project coordinator will assemble and direct technical party, properly dressed and wearing life preservers, to embarkation stations.
7. Person discovering FIRE shall immediately notify the bridge and fight the fire with available equipment.
8. Immediately upon the FIRE AND EMERGENCY signal, fire pumps to be started, all watertight doors, ports and air shafts to be closed, and all fans and blowers stopped. Fire hose to be led out in the affected area as directed.
9. Upon hearing the signal, MAN OVERBOARD, throw life ring buoys and lights overboard, stop engines, disengage shafts, and send lookout aloft. Emergency Boat Crew consisting of all seamen shall immediately clear lee boat for launching.
10. During periods of low visibility, all watertight doors and ports below the bulkhead deck shall be closed, subject to Master’s orders.

DECK DEPARTMENT

<table>
<thead>
<tr>
<th>No.</th>
<th>Rating</th>
<th>Fire &amp; Emergency Station</th>
<th>Boat #</th>
<th>Abandon Ship Boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Master</td>
<td>On bridge in command of all ops.</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>2</td>
<td>Exec. Officer</td>
<td>On location of emergency (in charge)</td>
<td>2</td>
<td>Port</td>
</tr>
<tr>
<td>3</td>
<td>1st Mate</td>
<td>On location of emergency - provide breathing apparatus, helps at scene</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>4</td>
<td>Seaman (113)</td>
<td>On location-provides fire hoses</td>
<td>2</td>
<td>Port</td>
</tr>
<tr>
<td>5</td>
<td>Seaman (119)</td>
<td>On location-provides extinguishers</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>6</td>
<td>Seaman (117)</td>
<td>On location-provides fire hoses</td>
<td>2</td>
<td>Port</td>
</tr>
<tr>
<td>7</td>
<td>Seaman (115)</td>
<td>On location-provides fire axe</td>
<td>1</td>
<td>Sbd</td>
</tr>
</tbody>
</table>

ENGINE ROOM DEPARTMENT

(On Duty)

<table>
<thead>
<tr>
<th>No.</th>
<th>Rating</th>
<th>Fire &amp; Emergency Station</th>
<th>Boat #</th>
<th>Abandon Ship Boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chief Eng. (301)</td>
<td>Secure engine room - start pumps</td>
<td>2</td>
<td>Port</td>
</tr>
<tr>
<td>2</td>
<td>1st Eng. (311)</td>
<td>Secure engine room - start pumps</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>3</td>
<td>Asst. Eng. (111)</td>
<td>Assist, secure engine room</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>4</td>
<td>Oiler (109)</td>
<td>Assist, secure engine room</td>
<td>2</td>
<td>Port</td>
</tr>
</tbody>
</table>

(Off Duty)

<table>
<thead>
<tr>
<th>No.</th>
<th>Rating</th>
<th>Fire &amp; Emergency Station</th>
<th>Boat #</th>
<th>Abandon Ship Boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chief Eng. (301)</td>
<td>Assist on scene leader</td>
<td>2</td>
<td>Port</td>
</tr>
<tr>
<td>2</td>
<td>1st Eng. (311)</td>
<td>Assist on scene leader</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>3</td>
<td>Asst. Eng. (111)</td>
<td>Assist on scene leader</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>4</td>
<td>Oiler (109)</td>
<td>Assist on scene leader</td>
<td>2</td>
<td>Port</td>
</tr>
</tbody>
</table>

STEWARD DEPARTMENT

<table>
<thead>
<tr>
<th>No.</th>
<th>Rating</th>
<th>Fire &amp; Emergency Station</th>
<th>Boat #</th>
<th>Abandon Ship Boat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chief Steward (309)</td>
<td>Secure galley-bring first aid kit</td>
<td>2</td>
<td>Port</td>
</tr>
<tr>
<td>2</td>
<td>1st Cook (303)</td>
<td>Arouse all passengers stbd side</td>
<td>1</td>
<td>Sbd</td>
</tr>
<tr>
<td>3</td>
<td>Galleyhand (307)</td>
<td>Arouse all passengers port side</td>
<td>2</td>
<td>Port</td>
</tr>
</tbody>
</table>

(PROCEED IMMEDIATELY TO ASSEMBLY AREA)

TECHNICAL PARTY

Test Conductor - Muster all personnel - Report to bridge and await further orders.
Technical Personnel - Proceed to assembly area (main deck forward) unless advised otherwise.
NOTE- Always wear life jacket - have survival suits in hand, wear protective clothing (long sleeves) and a cap.

Figure 1-1 Typical Ship’s Station Bill
HOW TO INFLATE THE LIFE RAFT

1. Untie on the slip-hook, REMEMBER! The painter must be fastened on board.

2. Raft is removed from cradle and thrown over board.

3. Haul in the painter to an approximate length of 25 m, then give a sharp pull and raft will inflate.

4. To board keep raft to ship's side, then jump onto or swim out to it.

5. Rescue line with raft

6. When all are on board cut painter. Knife and placed in front of raft

7. Throw out sea anchor

8. If raft should inflate up side down, stand up on a painter and head at the coast

Figure 1-2  Procedures for Inflating Life Rafts
**Condition II** - Condition II is set during periods of moderately heavy weather (nominally Sea States 4 through 6) and darkness. No personnel are allowed topside or on weather decks alone. When working near the side of the deck (e.g., launching or retrieving equipment), lifejackets and harnesses will be worn. Condition II may also be set when restricting access to some portion of the ship is required (e.g., for explosives handling).

**Condition III** - Condition III is set during periods of violent weather (above Sea State 6) when it is no longer safe to continue operations. Weather decks are secured to all personnel. No equipment will be launched or recovered when this condition is set.

The Test Conductor will inform all members of the test party regarding the current Operating Condition, and will update the notice when necessary. All members of the test party should be familiar with the meaning of each operating condition and should modify their activities accordingly.

Once underway, keep your personal gear properly secured or stowed. Frequently check your berthing area to ensure that there is nothing adrift that could cause injury. Be extremely cautious of wet decks, including those in head and shower facilities. Should you suffer a minor abrasion or sprain, watch the injury closely. If you do not think it is healing properly, see the Test Conductor immediately.

**SPECIAL OR HAZARDOUS OPERATIONS**

**Entering or Leaving Port**

Nothing can be more picturesque than sailing out of or into port. These evolutions usually involve periods of extensive maneuvering, during which the crew is busy. It is easy to be in the way or, worse, in danger as you enjoy the scenery. Unless you have been invited to the pilot house during this period, stay away. Also, stay clear of line handlers working fore and aft. It is easy and dangerous to step in a coil or “bight” of line, and a line parting under strain can cut a bystander in half. Topside amidships is usually the area of least activity; this position allows an open and excellent view of the landfall and harbor.

**Cold Weather**

Cold weather affects both people and equipment, and additional preparations are required to work effectively outside. Proper clothing is the key to comfort in this environment; clothing that is loose, warm, and fairly lightweight is best. It should be worn in layers, allowing you to remove some for inside work and to put them back on when you have to go outside. Some research vessels have on board Mustang Suits for use as an outer covering that provides some warmth, water repellence, and flotation if one falls overboard. These one-piece coveralls are tailored to allow freedom of movement and to trap air for warmth.

Proper shoes, gloves, and a cap are also essential. Low temperatures and high humidity will result in wet decks that can become covered with ice and very slippery in below-freezing temperatures. Shoes in addition to being water-repellent should provide good traction. Gloves must provide warmth and dryness. Two pairs, the outer one having water-repellent features, are recommended. Your hair is a good insulator; so a light cap is usually sufficient. The cap should include protection for the ears and forehead.
Unless you are working in extreme northern latitudes where temperatures drop well below freezing, frostbite is not a problem. However, hypothermia, or the lowering of the body’s core temperature, can occur, especially if you fall overboard or remain outside for an extended period after being soaked by rain or waves. Prior to the onset of hypothermia, your body will try to reduce heat transfer to the surface by constricting the near-surface blood vessels, resulting in pain and then numbness in the hands and feet. Uncontrolled shivering may follow as your body attempts to generate additional heat. Both of these conditions will make work outside difficult, and should be taken as warning signs of impending cold injury. Should you experience these conditions, it is important to begin rewarming yourself quickly. Get indoors and into warm, dry clothing. Warm liquids may be consumed.

**Working on Deck at Night**

Operating **Condition II** is always set between the hours of sunset and sunrise and governs work on deck during these hours. When this condition is set, working alone on the weather decks is prohibited. Have another person accompany you even if the job is short and you could do it alone. If the work to be done is near the side, have everyone involved wear a life jacket and safety harness. Prior to beginning work, get permission of the Test Conductor or his on-watch representative. Also notify the Test Conductor when you have completed the job.

**Working on Deck in Heavy Weather**

The Test Conductor will monitor the current and forecast weather and will modify the operating condition to ensure the safety of the technical party. During periods of moderate-to-heavy weather (Sea State 4 through 6) operating **Condition II** will be set. Guidelines for working outside under this condition are identical to those described above for working on deck at night.

Should the weather become severe (greater than Sea State 6), operating **Condition III** will be set by the Test Conductor. Under this condition, weather decks are secured to all personnel. No equipment will be launched or recovered when this condition is set.

**Falling Overboard**

Falling overboard will be a traumatic experience. From the minute you leave your feet or lose your grip, you must concentrate on your own survival. These instructions will maximize your chances of survival and recovery.

- Hold your breath when you hit the water; the buoyancy of your lungs will bring you to the surface. Do not try to swim frantically away from the ship; you will not be sucked into the propellers.

- Keep afloat and try to stay in the same area where you went in. Swimming unnecessarily wastes energy and results in increased heat loss. Once your absence is discovered, the ship will maneuver to retrace its track to you.

- Before the ship moves too far away, yell or scream to get someone’s attention. Loud screams can be heard up to 200 yards away.
• Do not discard any clothing unless it prevents you from keeping your head above water. Wet clothing will prevent some water circulation and thus retard heat loss. Do not use “drownproofing” in cold water; placing your head under water results in extreme and rapid heat loss.

• Get and keep a positive attitude about your survival! Your will to live affects your chances of rescue. Even if no one saw you go over, you will soon be missed and the search effort will begin immediately.

SHIPBOARD DRILLS

The Test Conductor in conjunction with the ship’s Captain will schedule emergency drills to familiarize the technical party with procedures in case of an at-sea emergency. Drills will be held at least weekly, and participation by the technical party is mandatory. The date and time of the drill will be announced beforehand. Your response during a drill should be exactly the same as it would be in a real casualty.

The ship’s bill located in your stateroom or berthing area describes your required actions and responsibilities in case of an emergency. On most research vessels, the response of the test party will usually be the same regardless of the type of emergency - collision, fire, abandon ship, etc. Upon sounding of the alarm signal, you can expect to muster in the designated assembly area wearing your life jacket and protective clothing (long-sleeve shirt, pants, and cap), and carrying your survival suit. You should muster in the assembly area immediately, prepared to abandon the ship with what you are currently carrying and wearing. Your expected response to these emergencies will be covered in detail by the Test Conductor at the safety briefing.

EMERGENCIES AND RESPONSES

Fire

In case of a fire aboard ship, quick response is the key to bringing the fire under control and extinguishing it. The ship’s crew is trained to fight shipboard fires and needs to be assembled quickly at the scene. The person who discovers a fire takes the first step in fighting the fire by reporting it. DO NOT TRY TO FIGHT THE FIRE IN LIEU OF REPORTING IT.

Should you discover a fire, or see or smell smoke or fumes, report the situation to the bridge or the Test Conductor as quickly as possible. If there is an internal communications circuit nearby, call the bridge or processing area. If there is no such means, direct another crew member or test party member to go to the bridge and report the fire, and if that is not possible, go yourself. Provide the following information about the fire:

• Location of the fire.
• What appears to be on fire or smoking (e.g., power panel, rags, spilled chemicals).
• Extent to which the fire has spread (e.g., is it confined to a trash can or is the entire lounge involved).
• Any personnel injuries at the scene.
Once you have reported the fire, return to the scene unless you are directed otherwise. Your primary job there is not to fight the fire but to ensure that the fire party comes to the proper area. This is especially important if they are trying to locate the source of fumes that you reported.

After reporting the fire (by intercom or messenger), you should take action to isolate the affected area. This means evacuating the space and other threatened areas, setting fire boundaries by closing doors or hatches, and if the fire is small (e.g., a paper fire in a trash can) beginning to fight it with the appropriate extinguisher. Figure 1-3 provides a brief description of the different classes of fires, the effectiveness of various extinguishing agents on these fires, and how to use the extinguishers.
# Correct Use of Fire Extinguishers

<table>
<thead>
<tr>
<th>Type</th>
<th>Class A Fires</th>
<th>Class B Fires</th>
<th>Class C Fires</th>
<th>Operating Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>Wood, cloth, paper, rubber, and many plastics etc., quench by water. Insulate with multi-purpose dry chemical or flood with Halon 1211.</td>
<td>Flammable and combustible liquids, gases, and greases. Burning liquids, cooking fats, etc., where smothering action is required.</td>
<td>Energized electrical equipment. Fire in motors, switches, appliances, etc., where a non-conducting extinguishing agent is required.</td>
<td>Hold upright, pull locking pin. Raise hose and squeeze lever. Direct the stream of water into the fire. Stream range: up to 40 feet.</td>
</tr>
<tr>
<td><strong>Carbon Dioxide</strong></td>
<td>Yes, Excellent. Water saturates material and prevents rekindling.</td>
<td>Yes, Excellent. Carbon dioxide leaves no residue, does not affect equipment or foodstuffs.</td>
<td>Yes, Excellent. Carbon dioxide is a non-conductor, leaves no residue, will not damage equipment.</td>
<td>Pull locking pin, and squeeze lever. Compressed CO₂ is discharged from 4 to 6 feet. Aim at base of fire. Sweep from side-to-side.</td>
</tr>
<tr>
<td><strong>(ABC) Dry Chemical</strong></td>
<td>Yes, Excellent. Fire-retarding coating to prevent reflash.</td>
<td>Yes, Excellent. Chemical powder smothers fire; screen of dry chemical shields operator from heat.</td>
<td>Yes, Excellent. Chemical is a non-conductor; screen of dry chemical shields operator from heat.</td>
<td>Pull locking pin, and squeeze lever. Aim nozzle at base of fire and sweep agent in side-to-side motion. Compressed dry air or nitrogen expels dry chemicals 12 to 20 feet.</td>
</tr>
<tr>
<td><strong>Regular Dry Chemical</strong></td>
<td>Not Recommended. Chemical powder smothers fire; screen of dry chemical shields operator from heat.</td>
<td>Yes, Excellent. Chemical powder smothers fire; screen of dry chemical shields operator from heat.</td>
<td>Yes, Excellent. Chemical is a non-conductor; screen of dry chemical shields operator from heat.</td>
<td>Pull locking pin, and squeeze lever. Aim nozzle at base of fire and sweep agent in side-to-side motion. Compressed dry air or nitrogen expels dry chemicals 12 to 20 feet.</td>
</tr>
</tbody>
</table>
Figure 1-3  Classes of Fires and Effective Extinguishing Agents
Aboard some ships, spaces housing extensive electronic and computing equipment are protected from fire damage by an automatically activated Halon fire extinguishing system. If such a system is installed, the Test Conductor will describe this system to the test party at the presail briefing.

**Collision**

A collision at sea is a serious incident that can result in extensive equipment damage, injury, and loss of life. There may be little notice that a collision is imminent. As a result, personnel are unprepared for the impact and are injured as they are thrown into equipment or bulkheads. If a collision does occur, the test party should take immediate steps to secure the laboratory area, and complete the following steps:

- Survey the area for integrity and safety. Loss of power or damaged equipment resulting in electrical fires will be the most likely occurrences in the lab area. Ensure that at least one exit from the space remains clear and usable. If the Halon fire extinguishing system is activated, evacuate the area immediately.

- Identify any injured personnel. Be particularly aware of possible shock victims. Communicate any injuries to the Test Conductor after you have surveyed the scene, but expect to provide first aid to injured personnel until assistance arrives.

- If power is still available to the lab, secure all nonessential equipment. Navigation and communication equipment should be left operating; it may be needed later for transmitting distress messages.

- Communicate the condition of the spaces and personnel to the bridge as soon as possible after making a complete evaluation. If no communications links remain, send a runner to the bridge. Break out life jackets and survival suits that are stored in the work spaces, and distribute these among watchstanders and injured personnel. Await further instructions from the Captain or mate prior to moving any large group of people to a new location.

**Man Overboard**

Should you see someone fall overboard or a person already in the water, immediately throw a life ring toward the person (don’t try to hit him). This will give the victim flotation and will provide a visual reference for the mate in guiding the ship back to the victim. If there is no life ring immediately available, throw anything that floats. If you have a watch with a stopwatch function, start it. This can help in determining when and where the victim entered the water.

Pass the word regarding the man overboard situation to the bridge or the Test Conductor immediately. If there is an internal communications circuit nearby, call the bridge or processing area. If there is no such means, direct another crew member or test party member to go to the bridge and report the man overboard; and if that is not possible, go yourself. The ship’s crew will respond by throwing additional liferings and lights overboard, maneuvering the ship to return to the victim, and preparing to lower a rescue boat. They will also send a man aloft to act as lookout.
The navigator will mark the chart and enter a waypoint in the Loran or GPS system, if available. He should also be ready to provide steering information to the bridge to help return to the man.

If, as a member of the technical party, you believe that a person is missing (e.g., if you can’t find your watch relief), immediately inform the Test Conductor or his on-watch representative. He should, as a precaution, have the navigator immediately mark the chart and enter a waypoint. He will also begin a quick search of the ship, page the individual, and ascertain from other personnel the last time the missing person was seen. If the individual is not found quickly (within 5 minutes), the Test Conductor should inform the bridge of the possible man overboard situation, and recommend to the mate or Captain that they suspend the experiment, commence a search along the previous track, and muster the technical party by sounding the General Alarm.

**Personnel Illness and Injury**

Personnel casualties aboard ship are usually the result of illness, not injury. These illnesses can vary from minor ailments, such as flu or sunburn, to life-threatening conditions, such as heart attack or hypothermia. Because medical facilities aboard ship are not extensive, early treatment for minor ailments is important to prevent the condition from worsening, and will minimize disruption to your experiments or to the ship’s operations. Should you develop an illness or condition requiring medical attention, see the Test Conductor immediately. He will have access to physician consultation services and can administer treatment programs, should one be necessary.

Working safely is a critical element in preventing personnel injury. However, if an accident should occur, the immediate application of first aid and medical treatment is important in saving the victim’s life or keeping his injuries from becoming life threatening. If you witness an accident or come upon an injured crewman, render first aid if you are trained to do so. If you are not, get help immediately by shouting for assistance, or by calling the processing area or bridge on an intercommunications circuit, if one is nearby. As a last resort, leave the scene to seek help. After you have notified the proper personnel, return to the victim and provide assistance to the medical personnel as they request.

**Abandon Ship**

The Captain’s decision to abandon ship is one of last resort, if necessary in order to save the lives of the crew and passengers. Once the decision has been made, all hands must carry out their duties quickly and without panic. Sounding of the General Alarm indicates a condition that if not corrected could result in the loss of the ship. When you hear this alarm, proceed to your berthing area, and put on protective clothing and your life jacket. Carry your survival suit and proceed to the main assembly area. Remember, you should leave your berthing area or stateroom prepared not to return. Once the decision to abandon ship has been made, a ship’s officer will apportion the technical party among the available life boats and will lead them to the boats for boarding. Proceed calmly to the boarding area and board the lifeboat when told to do so. One of the ship’s officers will board the boat as it is lowered away and take charge of the boat.

If a catastrophe renders the lifeboats unsuitable for use, the following safety precautions should be observed in abandoning ship:
• Wear a full set of clothing, including shoes and a soft cap or head covering as protection from exposure.

• Make sure all ties and crotch straps on kapok life jackets are snugly secured. Failure to do so may result in injury if jumping clear and will cause unnecessary suffering in the water.

• If time permits, go over the side by means of a line, ladder, or debarkation net.

• If it is necessary to jump, look first to be sure that the water below is clear of personnel or floating gear and wreckage.

• Always jump feet first; do not dive.

• Always abandon ship as far away from the damage as possible.

• Know the direction of the wind and go over on the windward side of the ship, if possible, to avoid flames, oil, and the ship itself from drifting on top of you.

• When in the water, concentrate on staying calm and avoiding panic. Use the following guidelines to enhance your chance of survival:
  - Conserve energy by moving as little as possible.
  - Keep clear of oil slicks if you can. Protect your eyes and breathing passages by keeping your head high or by swimming underwater.
  - If there is danger of underwater explosion, float or swim on your back as near to the surface of the water as possible.
  - If other persons are in the water, stay in a group. This will reduce the danger of attacks by sharks and will make rescue easier.
  - If the ship is sinking rapidly, swim clear quickly and tow injured persons clear, to avoid suction effect.

CHAPTER 2
SAFETY SUPERVISION

The Test Director is the focal point for test planning and plays a significant role in the safe execution and the successful outcome of the test. In composing the plan for any field test, his attention to employing the test platforms and installed equipment within their operational envelopes, ensuring test personnel are physically qualified and properly prepared, and adequately considering all contingencies are vital components of his major responsibility for creating a safe environment.

In the field, the Test Director monitors safe practices aboard the test platforms. During the mobilization and demobilization phases of the sea test, he monitors on a daily basis the status of upcoming and ongoing jobs. As supervisor of the technical parties aboard
the test platforms, he is likewise responsible for maintaining a safe environment and a high level of safety awareness throughout the at-sea portion of the field test.

**RESPONSIBILITIES**

In order to enhance the opportunity for safe completion of any field test, the Test Director must place high priority on safety in the test planning process. Completion of the following safety-related items is essential to maximizing the preparedness of test personnel and ensuring the appropriate level of contingency planning.

- Prepare a Field Test Safety Sheet specifically for the test and site as a supplement to the procedures contained in this manual. This sheet should cover essential information for test party members, such as appropriate clothing for the test including special safety clothing items, procedures for working and living safely on the various test platforms, and special safety precautions associated with operating test equipment. The Field Test Safety Sheet should also directly address unique safety hazards that will be present during the test (e.g., laser operations or use of caustic or hazardous chemicals). Last, this plan should contain contingency response procedures enabling the Test Director and test personnel to react properly in case of an accident or exposure to a specific hazard.

- Prior to commencing the test, prepare and present an operations briefing to all test participants. This briefing should include an overview of the upcoming test, the operations schedule, logistics and administrative matters important to the test party, and special safety considerations applicable to this test. The Field Test Safety Sheet should be distributed at or prior to this briefing.

- Complete a thorough discussion of the Operations Plan, including a detailed walkthrough of the upcoming operation and the intended movements and operations of the various platforms. The Test Director should also review the inventory and status of installed test equipment, special tasks to be completed prior to getting underway or upon completion of the test, and the qualifications and duties of the technical personnel embarked aboard his vessel.

The Test Conductor aboard each ship is responsible for coordinating the work of the embarked test personnel, and ensuring that they are aware of and follow the safety procedures. He should also keep the ship’s crew informed regarding the status of test operations and any special requirements placed on the ship or its personnel by the Operations Plan. In support of these responsibilities, he will complete the following tasks:

- Prepare and present a safety briefing to the technical party assigned to the vessel. The briefing should include information on proper responses to shipboard emergencies, use of personal safety equipment, and special hazards associated with the test operation itself.

- Prepare and submit to the ship’s Captain and the Test Director a crew list for technical party aboard the vessel.

- Schedule with the ship’s Captain weekly emergency drills for the technical party. Ensure that all members of the test party participate in these evolutions.
• Review procedures for all top-side evolutions, such as deploying or repairing instrumentation, with the work supervisor to ensure that appropriate safety measures are incorporated.

• Keep the Captain and on-watch mates informed of special test evolutions that may affect normal operation of ship’s systems or crew.

• Determine and update, as required, the current Operating Condition and post the information in the crew’s working and living spaces.

CHAPTER 3
SPECIAL OPERATIONS AND CONDITIONS

HEAVY WEATHER

The Test Conductor will monitor the current and forecast weather and will modify the operating conditions to ensure the safety of the technical party. During periods of moderate to heavy weather (Sea State 4 through 6), operating Condition II will be set. Under Condition II, working alone on the weather decks is prohibited; at least two persons will be assigned for any work on weather decks, even if the job is short or a simple one-person job. Everyone assigned to work in inclement (Condition II) weather will wear a life jacket and safety harness. The safety harness will be attached to a life line by means of the “D” rings provided on the belt.

Prior to beginning work, get permission of the Test Conductor or his on-watch representative. Also notify him when you have completed the job.

Should the weather become severe (greater than Sea State 6), operating Condition III will be set by the Test Conductor. Under this condition, weather decks are secured to all personnel. No equipment will be launched or recovered when this condition is set. Jacklines for emergency use should be rigged by the ship’s crew prior to the onset of heavy weather.

When heavy weather is forecast, the Test Conductor should ensure that all project equipment is properly secured prior to onset of the severe weather. These precautions should include securing equipment and instrumentation installed on the weather decks and loose gear in the processing area.

INSTRUMENT DEPLOYMENT AND RETRIEVAL

Deployments of oceanographic instrumentation are required in virtually all sea tests and have become a routine evolution. However, successful deployments require coordinating the work of numerous personnel, operating heavy machinery, and placing equipment under heavy loads in often less-than-ideal sea and weather conditions. Coupling these actions and environments without a conscious regard for safety can easily lead to personnel injury or loss. The following safety precautions must be followed when deploying and retrieving oceanographic instrumentation:

• All personnel involved in the deployment operation will wear life jackets. If working near the side of the boat or at a station where falling overboard is possible, personnel will wear a safety harness which will be attached to a lifeline or a part of the ship’s permanent structure.
• No persons will work “over the side” during normal deployment or retrieval operations.

• Personnel working with heavy loads or under parts of the ship’s structure (e.g. chain falls or U-frames) will wear hard hats.

• All deployment and retrieval operations will be conducted under the supervision of one individual who is responsible for both performance of the evolution and ensurance of safety precautions throughout the operation. He must supervise the work, monitoring the operations to ensure that the procedures used are proper and safe. If the operation is complex or the work area too large to be seen in its entirety, the supervisor will appoint a safety observer. The safety observer will be assigned no other duties.

ELECTRICAL SAFETY

Virtually all shipboard instrumentation and equipment installations require an interface with the ship’s electrical system. Improper installations, circuit loading, or fuse protection of project equipment can lead to equipment failure, personnel injury, or death. Therefore, work on the ship’s electrical system, including power generation and distribution systems, and safety systems, will be performed only by authorized members of the ship’s engineering department or by an APL-designated electrician. The following precautions apply to work with and around electrical systems:

• All crew members and technical party personnel shall constantly be alert for any indication of malfunctioning equipment. The senses of sight, hearing, smell, and touch all serve to make one aware of possible electrical malfunctions. If any signs of abnormality are noted, they shall be reported immediately to the ship’s engineering department.

• Heed all warning signs. They have been posted for your protection. A temporary DANGER or CAUTION tag attached to switches or receptacles indicates that work is being performed. Do not use or touch these items. Only those personnel who place these tags on circuits are authorized to remove them.

• Live electrical circuits shall not be exposed, but shall be enclosed in cabinets. Covers for all fuse boxes, junction boxes, switch boxes, circuit breaker panels, and wiring accessories shall be kept closed at all times when in normal use. Missing covers should be reported immediately.

• Always remove fuses or lock out main circuit breakers before working on any circuit. Do not trust the switch. Attach warning tags after pulling fuses or opening circuit breakers.

• In the event that door interlock circuits require bridging to aid in a repair, post one man to operate the main disconnect circuit breaker in case of failure or casualty.

• Personnel using portable electric tools shall wear safety glasses/goggles. Operators shall also wear hearing protection if tools produce hazardous noise
levels. Rubber gloves must be worn when using portable electric tools under hazardous conditions (e.g., wet decks or bilge).

- All portable electrical tools must be fitted with 3-pronged plugs having a grounding connector, or be double-insulated with a 2-pronged plug suitable for use with grounded type receptacles. (This may include personal appliances such as radios and electric shavers based upon the ship’s electrical safety program.) Only 3-wire extension cords which have only 3-pronged plugs and 3-slot receptacles shall be used with portable electrical equipment.

Computer and processing systems are commonplace in today’s at-sea environment. High voltages used in these equipments can be just as dangerous as electrical power distribution lines. Only properly trained electronics technicians should attempt to make repairs on these equipments. Additional safety precautions for work with electronic equipment must be followed:

- When testing high-voltage circuits in electronic equipment, ensure that the test probes have retractable prongs. If possible, use only one hand when making the test. Heavy rubber matting should be stood upon to preclude serving as a discharge to ground.

- Electronic equipment shall be cleaned only by experienced personnel.

- Ensure that high-potential portions of electronic gear are suitably guarded whenever power is applied. Do not work alone on electronic gear with dangerous high voltages present.

- Interlocks, and other safety devices such as overload relays and fuses, shall not be altered or disconnected, except for replacement.

- Discharge all high-voltage capacitors before working on electronic equipment. Store such capacitors with their terminals shorted.

Carbon dioxide (CO₂) is to be used in fighting electrical fires because it is nonconductive, thereby providing the highest degree of personnel safety, and because it offers the least likelihood of doing permanent damage. However if the discharge horn of a CO₂ extinguisher is allowed to accidentally touch an energized circuit, the horn may transmit a shock to the person handling the extinguisher. If CO₂ is not available, a dry chemical, Purple “K” (PKP), extinguisher should be used.

**HANDLING HAZARDOUS MATERIALS**

There are numerous materials aboard ship that present a threat to the safety of the personnel embarked. Most of these substances normally exist in liquid form (e.g., fuels and solvents), but equally hazardous materials may exist in solid and gaseous states. The five most common hazards posed by these materials are:

- High combustibility.

- Emission of toxic fumes.

- Irritation of the eyes and skin, if exposed.
• Creation of slippery decks when spilled and difficulty in subsequent clean-up.

• Combination of the hazardous material with other substances to create dangerous environments or atmospheres.

To avoid these threats, the following safety precautions will be incorporated in operations involving hazardous materials:

• Containers of flammable and combustible substances shall be closed and sealed when not in use. Highly flammable liquids (e.g., gasoline) shall be stored separately at locations where they can be jettisoned in case of fire or can be returned to an approved storage tank.

• Work areas where hazardous materials are being used shall be well ventilated.

• Know the specific hazards of the materials you are working with. Protective devices for clothing and eyes shall be worn as prescribed by the instructions on the hazardous material container. Antidote and decontamination procedures should be reviewed before beginning work. Phone numbers for the local Emergency Medical Services and Poison Control Center shall be posted at the nearest phone.

• No materials shall be used from unlabeled containers. All such containers shall be removed from the ship and disposed of properly. If contents of the container are unknown, contact port services for assistance in disposing of hazardous waste.

• Spilled fluids shall be cleaned up immediately to prevent the accumulation of toxic fumes.

• Paint and paint brushes shall be returned to the ship’s paint locker at the end of each day.

• Open-flame sparks and heat shall be kept away from spaces where flammable substances are stored. Placards shall be displayed warning personnel of the hazardous material storage.

• The following materials shall not be used or stored aboard any ship operated under APL charter or with APL personnel embarked:

  - Trichloroethylene
  - Benzene (Benzol)
  - Beta Naphthylamine
  - Carbon Tetrachloride
  - DDT Xylene Emulsion
  - Hydrocyanic Acid Gas
  - Insecticides or DDT
  - Methyl Bromide
  - Dry Cleaning Solvent (Stoddard Solvent) Type I
  - Tetrachlorothane
  - Tactical nuclear weapons (Actually these are not on the forbidden list, but I think they should be. RDC)
Do not dispose of hazardous materials into the ship’s drain systems or bilges. Place the material in a suitable container; seal and label it. In port, the disposal of hazardous materials and hazardous waste is a shore command function. Contact pier services for assistance. At sea, store the material in an approved storage area until the next port visit. Should you have questions about the handling or storage of hazardous materials ask the Test Conductor or Ship’s Engineer.

WORKING WITH HIGH-PRESSURE AND COMPRESSED GAS SYSTEMS

Numerous activities in the field require use of gases stored under high pressure. The most common shipboard high-pressure system is high-pressure air. This air is stored in a flask or reservoir and is distributed throughout the ship by a piping system. High-pressure air is used to operate pneumatic equipment, to recharge reservoirs (e.g., air guns) or, through the use of pressure reducing valves, to supply a low pressure air system.

- High-pressure air lines should be protected from crimping, denting, or rupture; if running on open deck, they should be bridged with scrap lumber or plate steel to avoid damage.
- Do not use high-pressure air to clean surfaces. Small items and debris may be propelled into personnel or equipment by the high escape velocity of the air. Use low-pressure air for this purpose.

Cylinders of compressed gases are potential explosion, fire, and health hazards if strict compliance with the applicable safety precautions are not followed. Safe practices when using compressed gas cylinders are listed below:

- Use compressed gas cylinders in an upright position. Secure the cylinders to prevent accidental falling.
- Always replace the metal cap on the cylinder to protect the cylinder valve. A blow to the unprotected cylinder valve could release gas under high pressure. Always transport and load gas cylinders with the protective caps in place.
- Threads on the regulator or union shall correspond to those on the cylinder valve outlet. Do not use adapters.
- Open cylinder valves slowly.
- Do not use a cylinder of compressed gas without a pressure-reducing regulator attached to the cylinder valve, except where the cylinders are attached to a manifold. In this case, the regulator should be attached to the manifold header.
- Before making the connection to a cylinder valve outlet, slowly open the valve for a instant to clear the opening of dust particles. Point the valve away from all personnel. Never open the valve near welding work, sparks, or open flame.
- Use regulators and pressure gauges only with gases for which they are designed and intended.
- Tightly close the cylinder valve when repairing a leak between the cylinder and the regulator.
• Before removing a regulator from a cylinder valve, close the cylinder valve and release the gas from the regulator.

• Do not take compressed gas cylinders into tanks, voids, closed spaces, or containers.

• Do not allow sparks, molten metal, or electric currents to contact the cylinder.

• Personnel servicing refrigeration systems using halocarbons (Freon, etc.) should wear safety goggles, elbow-length gloves, an apron or coveralls, and boots to prevent freezing of the eye or skin in case of an accidental discharge.

• Avoid all contact with grease and lubricants when handling or storing oxygen (O₂) cylinders. Do not use oil or grease as a lubricant for fittings or attachments on (O₂) cylinders. Using oil-contaminated fittings may result in an explosion of the cylinder itself.

• Under no circumstances should oxygen be used to start engines, preheat burners, operate pneumatic tools, or as breathing air for supplied air respirators.

• Never hammer or strike the valve wheel in attempting to open or close the cylinder valve. Use only wrenches, keys, or tools provided by the cylinder manufacturer. If the valve does not open easily, return it to the supplier.

• When loading or transferring cylinders, especially when using a crane or derrick, secure the cylinders in a cradle, suitable platform, rack, or special container. Slings or electromagnets will never be used to transport cylinders. Cylinders moved by hand shall be tilted slightly and rolled on the bottom edge without dragging or sliding. Cylinders transported by hand truck shall be securely held in position by chains, steel strapping, or other means to prevent the cylinders from falling off the truck.

• Valve protection caps shall not be used for lifting cylinders from one vertical position to another. Bars shall not be used under valves or valve protection caps to pry cylinders loose when frozen. Warm (not boiling) water shall be used to thaw cylinder valves and caps.

• When not in use, gas cylinders shall be stowed in well-ventilated spaces.

• Compressed gas cylinders shall not be stored near sources of heat (in excess in 130°F).

• Combustible gas cylinders shall not be stored with oxygen gas cylinders. Oxygen cylinders may be stored with inert gases such as helium, carbon dioxide, argon, or nitrogen.

• Acetylene and liquefied gas cylinders shall be stored valve-end-up.

• Cylinders shall be secured with metal collars or chains to prevent capsizing during heavy weather.

• Empty and full gas cylinders shall be stored separately.
• All personnel should be aware of the health hazards associated with compressed gases with which they are working. Before entering a space where compressed gas cylinders are stored, personnel shall ensure that the supply and exhaust ventilation systems have been in operation for at least 10 minutes, and that the space has been certified “gas free” by the ship’s engineer. One worker, aware of the potential hazards of leaking gases, shall remain at the entrance while others are working in the storage area.

WORKING OVER THE SIDE

When the ship is in port, no person shall proceed to work over the side without first obtaining permission from the Test Conductor. The term “over the side” includes any part of the ship outside the lifelines or bulwarks. The Test Conductor, prior to granting permission, must inform the ship’s Captain, senior mate on board, or the Officer of the Deck (in case of a Naval ship) of the planned work and location. At sea, no work over the side shall be done by members of the technical party except under the most unusual circumstances, and then, only if the work cannot be performed by a member of the ship’s crew. If a member of the technical party must be sent over the side when at sea, prior permission of both the Test Conductor and the ship’s Captain or Commanding Officer is required.

Personnel working over the side of the ship, both in port and at sea, shall wear life jackets and safety harness, and shall use appropriate tending lines. The safety harness will be equipped with a shock absorber (if working from a suspended stage, cargo net, or bos’n chair) attached to a “D” ring and a 1/2-inch diameter nylon safety line tended by a man on deck. The line tender must be present at all times. If the work is being performed at sea, a mate must also be present for the entire evolution.

Those personnel granting permission for the work to be done will be informed when it has been completed.

WORKING ALOFT

No person shall go aloft on masts, stacks, or kingposts without first obtaining permission of the Test Conductor. The Test Conductor, prior to granting permission, must inform the ship’s Captain, senior mate on board, or the Officer of the Deck (in case of a Naval ship). In addition, he shall ensure that all energized HF and MF radio transmitters have been placed in the standby position, that all energized radar transmitters are placed in the standby position, that power has been secured to all radar antennas, and that controls for these equipments have been marked “SECURED: PERSONNEL ALOFT.” If VHF or UHF transmitters are in an active status, the Test Conductor shall ensure that personnel going aloft are informed of the status, number, and locations of all transmitters in use. The engineer on watch shall also be notified so that he does not lift safety valves while personnel are aloft near the stacks. Those personnel granting permission for the work to be done shall be informed when it has been completed.

Personnel going aloft shall abide by the following safety precautions:

• Personnel shall be equipped with a parachute-type safety harness, safety lanyard, working lanyard, and a climber safety device (if a climber safety rail is installed). They should wear properly fitted clothing (not overly loose or baggy).
• In order to keep the lanyard continuously attached to a fixed structure, with a minimum of slack, the attachment point of the lanyard shall be appropriately changed as the work progresses. Care shall be exercised to ensure that the lanyard is not cut, pinched, or pulled over a sharp edge.

• Ensure a good footing and grasp at all times. Keep either the safety or working lanyard secured at all times except when actually ascending or descending.

• Personnel going aloft shall be assisted by another person who will act as a safety observer/line tender.

• The area below the man aloft will be kept clear of all other personnel. All tools and equipments will be secured with preventer lines.

CHAPTER 4
MEDICAL EMERGENCIES AND EVACUATION

ILLNESS AND INJURIES

The Test Conductor and the ship’s Captain are responsible for the health and welfare of the technical party and crew, respectively; and both must be prepared to respond to illness and injury at sea. For operations involving large numbers of test personnel (nominally 25 or more), APL usually hires registered nurses (RNs) or emergency medical technicians (EMTs) trained in critical care and assigns them to the participating research platforms. When a nursing professional is embarked, he or she is responsible for monitoring the health of those assigned to the technical party, and is the primary treatment provider in case of illness or injury. The majority of the at-sea tests, however, will not have a nurse embarked; the Test Conductor assumes this responsibility for the technical party. To supplement the Test Conductor’s first aid training, JHU/APL can contract with Medical Advisory Systems, Inc. (MAS) to provide assistance, advising treatment or procedures to follow if faced with a significant casualty. MAS provides continuous access to a physician via telephone (including Inmarsat), TELEX, or high-frequency single-side-band (HF-SSB) radio. MAS has access to a variety of physician specialists should conditions warrant.

Contracting with MAS to provide an elevated level of care is strongly recommended for all JHU/APL tests where technical personnel are embarked on civilian research vessels and when operations are to be conducted at least 24 hours transit time away from shore. As part of the test preparation process, the Test Conductor should determine the need for MAS services and, if warranted, initiate a contract action nominally 60 days prior to commencing the test. Approximately 30 days prior to getting underway, the Test Conductor should furnish MAS with particulars of the test so that they may prepare a list of recommended medical supplies and equipment.

For field tests where the technical party is small and operating close to a suitable port, a review of the ship’s medical preparedness is still warranted. As part of the test preparation process, the Test Conductor should ensure that the crew has one member trained in First Aid, and that the ship’s medical supplies are adequate for the number of personnel embarked and the planned mission.

As an alternative to MAS physician consultation services, the Coast Guard and other international lifesaving agencies are available to provide medical advice through the DH MEDICO program. This free service furnishes medical advice by radio 24 hours every day.
MEDICAL EVACUATION

Should an illness or injury be severe enough that treatment and recovery are not likely at sea, medical evacuation (MEDEVAC) of the person to a properly equipped facility will be necessary. The decision to MEDEVAC an individual is a major one, and most times, adversely impacts test success. However, any delay in making this decision, hoping that the patient’s condition might improve, could have serious consequences. If in the course of treatment, a consulting physician, the ship’s Captain, or the Test Conductor recommends that the patient be evacuated, the Test Conductor will request that the ship’s Captain conduct the evacuation at the earliest possible opportunity. Coordination and conduct of the evacuation, either by helicopter, to another boat, or directly to shore should be completed by the ship’s crew.
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Appendix B. Nautical Terms

The vast majority of this glossary of nautical terms was assembled by Elizabeth Guillard of Woods Hole Oceanographic Institution [Guillard, 1975].

ABAFT - behind or aft of, toward the stern
ABEAM - a direction at right angles to the ship’s length; on the beam
ABOARD - on or in a vessel. Close aboard is close to another ship or an obstruction
ABREAST - alongside of; on the beam
ACOUSTIC WIRE - same as hydro wire but with electrical conductors built in
ADCP - Acoustic Doppler Current Profiler
AFT - toward the stern; in the stern
AGENT - see “ship’s port agent”
ALOFT - above the decks as on the mast or in the rigging
AMIDSHIPS - midway between bow and stern, in the line of the keel
ASTERN - toward the rear of the vessel; behind the vessel; backward progress
ATHWARTSHIP - at right angles to the fore and aft line
BEAM - the greatest width of a vessel
BEARING - the compass direction of an object or destination from the ship. Relative bearing is the direction relating to the ship with the bow 0° and the stern 180°. True bearing is the direction from the ship relating to true north with north being 0° and south 180°
BELAY - to temporarily secure a line without knotting by making one or more ‘S’ turns (varying somewhat with synthetic lines) around a cleat or pin
BELOW - downward, within ship
BEND - to fasten one line to another or to a spar
BERTH - bed or bunk; the position where a ship ties up or anchors, a position of employment aboard a ship; a margin of safety in the distance from which another vessel or object is passed, as in “giving wide berth”
BIGHT - a doubled or looped part of a line; cove or indentation along a coastline
BITTER END - the other end of the line or cable from the end that is performing work; the end that is on the winch or the bitts
BITTS - iron or wooden posts set vertically to which lines can be made fast
BLOCK - a mechanical contrivance of one or more grooved pulleys (sheaves) through which turns of line (falls) are threaded for the purpose of gaining mechanical advantage or changing the direction of motion
BOATHOOK - a long sturdy pole fitted with a blunt hook at one end
BOATSWAIN, alt. BOS’N, pron. BOS’N - top ranking seaman, oversees deck crew, maintenance and upkeep of the ship except for the engine room and galley areas
BOW, pron. BOUGH - the foreward end of a vessel
BRIDGE - area above the main deck from which the ship is navigated and steered; also, the officer(s) on duty in the command area
BULKHEAD - nautical equivalent of wall
BULWARKS - fence-like guard along edge of deck
BUNK - bed, berth
BUOY - floats of a variety of designs and shapes, usually moored, used as navigational aids, markers for moorings or underwater objects, or to support test or scientific gear
CAPSTAN - a revolving cylindrical device used for heaving in lines
CAST OFF - to let go a line; to leave a dock or anchorage
CHAFING GEAR - canvas, rope or other material used as wrappings to prevent wear from chafing
CHART - the nautical equivalent of a map
CLEAT - a double-horned piece of wood or metal around which lines are made fast; v. to belay
COURSE - the compass direction along which the vessel (not equivalent to “heading”) is intended to go or is traveling
CROW’S NEST - a lookout or observation station high up on a mast
CTD - Conductivity, Temperature, and Depth profiler
DEAD AHEAD - directly in front of the vessel
DECK - nautical equivalent of floor
DOG - heavy latch by which doors, hatches, portholes, etc. are secured; v. to latch
DRAFT - the distance from a vessel’s water line to the deepest part of the hull; the depth of water necessary to float a vessel
EASE OFF - to slack off or release tension slowly and smoothly
EYE - a loop or hole which is spliced or tied on the end of a line
FATHOM - six feet; 1.83 meters
FANTAIL - after part of main deck from which most scientific work involving heavy gear is done
FEND OFF - to prevent touching, in coming or bringing alongside the ship
FIX - a vessel’s position determined by navigation data
FAIRLEAD - a chock or hole, block or sheave, through which a line may be run without danger of chafing or jamming, so as to provide a smooth run or change of direction
FLYING BRIDGE - the highest navigation bridge
FORE - toward bow
FORECASTLE, pron. FO’C’SL - uppermost and most forward enclosed area on the ship; also, crew’s quarters
FOREDECK - the exposed deck forward of the ship’s superstructure
FOUL - the opposite of clear, as in tangled lines or chain, or bad weather
GALLEY - nautical equivalent of kitchen
GUY - a supporting or steadying line or wire
HATCH - opening in ship’s deck for access to space below (hold)
HAUL - to pull
HEAD - the compartment containing a toilet; the toilet itself
HEADING- direction in which ship’s bow is pointing at any instant, not the same as course!
HEADWAY - the forward motion of the ship under power
HEAVE - vertical motion of the center of the ship
HEAVE TO - to reduce the power until the ship is just maintaining steerage with little or no headway, e.g., to perform scientific activities or ride out rough seas
HELM - wheel, tiller; the controls for a vessel’s steering apparatus
HOLD - beneath-decks storage area
HYDRO WIRE - steel wire, normally used to support lightweight over-the-side sampling apparatus such as Nansen bottles, gravity corers, etc
INSHORE - near or toward the shore
KEEL - the backbone of a vessel, running fore and aft along the center line of the bottom of the hull
LADDER - stairway between decks
LASH DOWN - tie down, secure
LEE - the side of a ship, or a shore location, sheltered from the wind
LEEWARD - toward the lee; away from the wind
LEG (of a cruise) - the working portion of a cruise between ports. A long cruise may have many legs
LINE - a piece of rope is called line once it leaves the rope reel and is put into use
LOG - a record of all the activities aboard a ship; a device for measuring ship’s speed and distance traveled
MAKE FAST - tie with a line; make secure
MARLINE, pron. MARLIN - tarred twine used for seizing and light lashing
MASTER - the captain of a vessel
MESS DECK - where meals are eaten
MILE, NAUTICAL - equals 6,079 ft; 1.15 statute or land miles, 1,852 meters, or approximately one minute of latitude
ON THE BEAM - the direction at right angles to a ship’s heading or the line of her keel
ON THE BOW - a direction of forty-five degrees or less from the bow
ON THE QUARTER - a direction of forty-five degrees or less from the stern
OVERBOARD - over the side of a vessel
OVERHEAD - nautical equivalent of ceiling
PAINTER - the line in the bow of a boat for towing or making fast
PART - break, e.g., the line parted under strain
PAY OUT - to let out chain, line, or wire
PITCH - angular motion about the athwartships axis of the ship
PORT - when facing forward, the left side of the vessel
PORTHOLE - circular openings in a ship’s hull for ventilation and light
QUARTER - the part of a vessel forward of the stern and abaft of the beam
RAIL - top edge of bulwarks
REEVE - to pass a line through a block
ROLL - angular motion about lengthwise axis of the ship
RULES OF THE ROAD - the laws of navigation at sea that bear on safety and the avoidance of collision
RUNNING LIGHTS - the usual navigation lights carried when a vessel is under way
SEABAG - a soft, cylindrical fabric bag for clothes, personal possessions
SECURE - to fasten, tie down, make safe and shipshape
SEIZE - to bind with marline or wire to prevent accidental opening or unraveling
SET - that component of the movement of a ship, caused by current or tide, not in the
direction in which the ship is heading
SHACKLE - a U-shaped fitting with a pin across the open ends, the pin sometimes being
threaded at one end and sometimes held in place with a cotter pin, or both
SHEAVE - (pronounced shiv) wheel with grooved edge such as is mounted in a pulley block to
guide the cable
SHIP’S PORT AGENT - a business firm that sells its services to organizations that operate
vessels. In each port away from home the agent provides services such as loading and
unloading, shipping, dealings with local maritime, customs and immigration authorities,
referral to reputable repair facilities, etc. Mail is addressed in care of the agent for the
next port to be entered
SKIFF - technically, a flat-bottomed boat, but often used to name any small boat for rowing,
sculling, or fitted with an outboard motor
SIX-THREAD - 1/4" manila rope useful for lashing down and securing lighter gear in
staterooms and labs
SOUNDING - depth measured; the number indicating depth on a chart; the process of
measuring fuel or water in a ship’s tanks
SPLICE - to join two lines by interweaving and tucking together individual strands in a
prescribed pattern
STARBOARD - looking forward, the right side of a vessel
STANCHION - a movable vertical support for lifelines
STEERAGEWAY - the minimum amount of speed required to maintain control of the ship
with her rudder
STERN - the after part of a vessel
STOW - to put anything away for sea; to put gear in its proper place
SWAB - a rope or twine mop; v. to mop
SWINGING SHIP - the process of checking the accuracy of and adjusting the ship’s magnetic
compass
SUPERSTRUCTURE - that part of the ship above the main deck
STATEROOM - cabin; sleeping compartment
THIMBLE - a pear-shaped grooved metal fitting around which an eye splice is made
TOPSIDE - above the main deck
TRAWL WIRE - heavy-duty wire used to lower heavy instruments overboard from the trawl
winch
TWO-BLOCK - to reach the end; to bring one object hard up against another, as when an
instrument on the end of a wire is hauled hard up against the block through which the wire
runs. May occur slowly and intentionally or suddenly and unintentionally
UNDER WAY - when the anchor has been weighed or the lines cast off. Strictly speaking, a
vessel can still be under way even though stopped, as long as she is not connected to the land
UNOLS - University - National Oceanographic Laboratory System, the organization that manages the U.S. academic research fleet
UNREEVE - to haul a line out of a block, fairlead, etc
VESSEL - a general term for a floating structure that carries passengers, cargo or both
WATCH - a work period generally four hours long; also refers to those standing watch as an individual, pair, or group
WAY - a vessel’s movement through the water
WEATHER- toward the point from which the wind blows, as in weather side of the ship, the side from which the wind is blowing; weather
WINCH - motor-driven drum onto which line or wire is wound; v. to winch onto the drum
WINDWARD - the direction from which the wind is blowing; weather side of the ship
YACHT - A boat that is too expensive for an oceanographer to afford. Personally I think the individual who decided upon the weird spelling of yacht should be shact
YAW - side to side movement of the bow of the ship
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Appendix C. Annotated Packing Lists

Within this appendix are typical lists of items that I would pack for a two-week cruise. On such a cruise I have three lists: instrumentation and support equipment, general-purpose tools and test equipment, and expendables. I have not included here a list of instrumentation and support equipment because that list is specific to each individual cruise. I hope that you’ll find the general purpose lists useful though when making up your own lists.

### General Purpose Tools and Test Equipment

<table>
<thead>
<tr>
<th>Qty</th>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>Computer system with monitor, keyboard, mouse, external disk drives, networking boards</td>
<td>Actually I very rarely take 97 computers into the field for one experiment, but it usually seems like it. Remember to bag and label all cables, mice, etc. to ease the set up of each system.</td>
</tr>
<tr>
<td>2</td>
<td>Laser printers</td>
<td>For larger experiments I prefer to take 2 printers, in case one fails. On smaller experiments, I’ll use an older dot matrix printer as the backup.</td>
</tr>
<tr>
<td>1</td>
<td>SA-10 Stereo Amplifier</td>
<td>My amplifier and speakers are high on my list because I love listening to music while I work. Just remember to bring along a pair of headphones so that you can listen to your music without disturbing others. My rule is that if anyone in the lab objects to either the choice or the existence of music in the lab, I switch to headphones. After all, how would you like it if someone brought along a stereo but just wanted to listen to, and here I will coin the world’s most redundant phrase, bad disco music.</td>
</tr>
<tr>
<td>1</td>
<td>Heat gun</td>
<td>These are great for heat shrink tubing, but I find the 500° setting a bit harsh for drying my hair.</td>
</tr>
<tr>
<td>1</td>
<td>Spare IC case</td>
<td>I have a case with a bunch of drawers that contains a wide assortment of useful integrated circuits. It contains specific spares for my systems along with some generally useful parts for jury rigging new systems. In a separate binder I take data sheets for the ICs in my case, preferring the data sheets to whole data books due to their smaller size.</td>
</tr>
<tr>
<td>2</td>
<td>Clipboards</td>
<td>Handy when working with checklists.</td>
</tr>
<tr>
<td>1</td>
<td>Machinist vise</td>
<td>Useful for holding smaller pieces when drilling.</td>
</tr>
<tr>
<td>1</td>
<td>Wire wrap gun</td>
<td>If you don’t use wire wrap, don’t bother.</td>
</tr>
<tr>
<td>2</td>
<td>Hardware cabinets</td>
<td>It’s a good idea to pack an assortment of nuts, bolts, standoff and washers.</td>
</tr>
<tr>
<td>1</td>
<td>Complete set of manuals for all instruments, computers, programming languages and systems</td>
<td>Very important! If something breaks, whether it is hardware or software, you want to be able to fix it.</td>
</tr>
<tr>
<td>1</td>
<td>500’ of 3/4” polypropylene braided line</td>
<td>A spool of line is always handy, if for no other reason than lashing a difficult colleague to the forward crane.</td>
</tr>
<tr>
<td></td>
<td>Item</td>
<td>Description</td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>Flashing warning lights</td>
<td>Every buoy should have a flashing warning light attached to it. I usually try to pack 1 or 2 extras. I have been on cruises where other scientists forget theirs and I have also been out where we threw together a complete mooring, which we had not planned, from spare parts lying around the ship.</td>
</tr>
<tr>
<td>1</td>
<td>Battery charger</td>
<td>If you use lead acid batteries, take a charger. This will allow you to work on your system on deck prior to deployment without wearing down the batteries.</td>
</tr>
<tr>
<td>2</td>
<td>Adjustable power supply</td>
<td>My experience has been that power supplies are the most common thing to fail on board ship, and so an extra adjustable supply which can be wired into a piece of equipment can be a life saver.</td>
</tr>
<tr>
<td>1</td>
<td>RS232 Breakout Box</td>
<td>The RS232 serial communications standard is anything but. There are so many variations of connectors, handshaking schemes, and pin placements that its a wonder anyone can get it to work. An RS232 breakout box, allowing you to visualize individual signals on LEDs and swap pin connections around, is the Rosetta stone for this modern Tower of Babel. (How’s that for a mixed historical reference.)</td>
</tr>
<tr>
<td>1</td>
<td>Oscilloscope, Tektronix 465</td>
<td>I once went on an experiment without an oscilloscope, and it turned out to be a big mistake. Usually, when I take it, I don’t need it, but when you do need it nothing else will do.</td>
</tr>
<tr>
<td>1</td>
<td>Capacitance Meter</td>
<td>Ever since my tussle with the out-of-spec CTD cable, I pack a capacitance meter.</td>
</tr>
<tr>
<td>2</td>
<td>Fluke Multimeter</td>
<td>I like the Fluke, but a good multimeter is a must for troubleshooting simple problems.</td>
</tr>
<tr>
<td>1</td>
<td>Receiver ICM IC-R7000</td>
<td>A broadband communications receiver can be great for checking out transmitters and modems on telemetry systems. In coastal areas its also good for FM radio.</td>
</tr>
<tr>
<td>1</td>
<td>Parka</td>
<td>While I have listed this elsewhere as clothing, parkas and rain gear are usually bulky enough that I ship them in with the rest of my equipment, instead of hand carrying them in my sea bag. The only problem with this approach is that you may need your gear immediately if it is cold or raining when you perform your onload.</td>
</tr>
<tr>
<td>4</td>
<td>Rainwear Sets (2M,2XL Overalls + 1M,3L Jackets)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>DC voltage standard AN3100</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Sweep Function Generator, Model 3020</td>
<td></td>
</tr>
<tr>
<td>1 ea.</td>
<td>Sling Psychrometer</td>
<td>Even though we deploy expensive electronic equipment to measure temperature and humidity I like the backup of handheld instruments in case all else fails.</td>
</tr>
<tr>
<td>Handheld Hygrometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handheld Wind Sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical Range Finder</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass thermometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handheld digital compass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Deck Chairs</td>
<td>I like my deck chairs, but only take a luxury item like this if you’re sure there is room. My chairs fold up and so they can be easily stowed when not in use. Don’t take large bulky items that will be in the way of others trying to do their work.</td>
</tr>
<tr>
<td>1</td>
<td>Coax Connector Crimp Tool RG-58 &amp; RG-59</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>Item Description</td>
<td>Notes</td>
</tr>
<tr>
<td>----------</td>
<td>----------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td>Power Drill</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Caliper</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Jigsaw</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Cutter</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Micropress Tool</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Cordless Screwdriver Set</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Winch</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Nikon F3 Camera with motor drive, data back, and lens assortment WITH film</td>
<td>I prefer to take a lab camera on cruises. I feel that documenting the cruise activities is a legitimate expense. Furthermore I have found that the salt air is tough on cameras, making me reluctant to risk my personal camera.</td>
</tr>
<tr>
<td>1</td>
<td>Tool Chest, Roll-away</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Shipping Container</td>
<td>If you have enough equipment to ship to the on load site, consider buying an entire 20- to 40-foot shipping container. They protect your equipment during shipping, can provide an enclosed working area during on load, and are handy for storage while you are at sea.</td>
</tr>
<tr>
<td>2</td>
<td>Carrying Case</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Honda AC Generator</td>
<td>In some cases, a small generator is handy for getting power on deck. Just be sure to check with the crew first, as it is likely there are strict regulations on gasoline storage on board.</td>
</tr>
<tr>
<td>1</td>
<td>Tape measure, 30 m metric</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Tape measure, 3 m</td>
<td></td>
</tr>
</tbody>
</table>
Typical Expendable Supplies List

<table>
<thead>
<tr>
<th>Qty</th>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>Tie wraps giant</td>
<td>Without tie wraps and duct tape, oceanography as we know it would cease to exist. Tie wraps are useful for securing and dressing cables around a ship or buoy. We also use them to secure the bit in a shackle as well as backups to instrument mounting flanges. The medium size is most useful for securing cables, the large are best for securing large objects.</td>
</tr>
<tr>
<td>400</td>
<td>Tie wraps large</td>
<td>A major problem with the use of tie wraps is that a relatively sharp portion protrudes out from the cable bundle making handling of the cable bundle difficult. Don’t use tie wraps to secure bundles you’ll be working with by hand.</td>
</tr>
<tr>
<td>600</td>
<td>Tie wraps medium</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>Tie wraps small</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>Tie wraps medium with tabs</td>
<td>These tie wraps are secured to the end of individual cables. The name of the cable is then written on the tab with a permanent marker to identify the cable.</td>
</tr>
<tr>
<td>1</td>
<td>Bungee Cord, Roll</td>
<td>Bungee cord is used to tie computers and lab equipment down to the tables within the lab so they don’t shift in heavy seas. Bungee is also useful for a poor man’s shock absorber.</td>
</tr>
<tr>
<td>20</td>
<td>Bungee Cord Ends, Assorted</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Masking tape 2 in</td>
<td>We use tapes of all varieties at sea. Masking tape is handy for temporary labeling of cables and boxes.</td>
</tr>
<tr>
<td>2</td>
<td>Masking tape 1 in</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Duct tape</td>
<td>Duct tape is a generic cloth-covered wide tape that is used for tapping together cable bundles and securing wires. When one of my buoys is deployed it is usually covered with this stuff. My colleagues tell me its unprofessional, but my cables don’t strum and securing the cables minimizes strain on connectors.</td>
</tr>
<tr>
<td>2</td>
<td>Rolls colored tape</td>
<td>Colored tapes can be useful for marking instruments, making them easier to identify at a distance. They can also be used to mark cable lengths, with a black mark every 50 m, a yellow mark every 250 m, and so on.</td>
</tr>
<tr>
<td>9</td>
<td>Filament tape 3/4&quot; Scotch 880</td>
<td>Filament tape is extremely strong and useful for packing boxes at the end of an experiment.</td>
</tr>
<tr>
<td>10</td>
<td>Tape vinyl Scotch 88</td>
<td>Vinyl electrical tape is used to insulate exposed electrical connectors. It does not hold up well when exposed to the environment and can become brittle after several weeks of exposure to the sun.</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th><strong>Tape rubber splicing Scotch 23</strong></th>
<th>Rubber splicing tape is amazing. It is applied by first removing the plastic mesh on one side of the tape. The tape is then stretched to 50% of its original length, and wrapped about the connection tightly. After a few hours the tape bonds to itself forming a solid rubber seal. Attention should be paid to the end of the tape to insure that it doesn’t unravel prior to the tape bonding. While this tape cannot withstand direct exposure to sunlight, it can form a watertight seal. I use this, followed by a coating of Scotchkote 3M, for sealing underwater connections. For weathertight connections that will be exposed to the sun I include an outerwrap of vinyl or duct tape, just to protect the rubber tape. This tape must be removed with a sharp knife and some patience after the rubber has sealed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Tape coax-seal</strong></td>
<td>This tape is handy for sealing coaxial connectors to the weather, although the rubber splicing tapes can also do a good job.</td>
</tr>
<tr>
<td>3</td>
<td><strong>Copper tape 1”</strong></td>
<td>I often find that the electromagnetic interference from the ship’s radars or communication systems get into my signals from shipborne instruments. For this reason I prefer to use shielded cables for long data runs around the ship with the cable shield grounded at one end. (Grounding both ends often sets up ground loops due to potential differences between various points on the ship. The currents induced in the shield by these potentials can cause more noise than in an unshielded cable.) The copper tape is handy for shielding non-metallic junction boxes and the like.</td>
</tr>
<tr>
<td>1</td>
<td><strong>Teflon tape 3/4”</strong></td>
<td>Teflon tape is used by plumbers on pipe threads to insure a good seal to keep water from leaking out. This tape is what mathematicians call commutative, meaning that it will also keep water out. This is handy for oceanographic applications because salt water and electronics do not mix.</td>
</tr>
<tr>
<td></td>
<td><strong>Teflon tape 1/2”</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td><strong>Collection of heat shrink tubing</strong></td>
<td>Heat shrink tubing is good for insulating connections, although due to topological contraints you should be sure to apply the tubing prior to making the solder connection.</td>
</tr>
<tr>
<td>??</td>
<td><strong>Battery D-cells</strong></td>
<td>A collection of batteries comes in handy. The D- and C-cells are useful for flashlights. The AA- and AAA-cells are used in various hand-held instruments and personal entertainment devices. Take an inventory of all of your battery-powered devices to determine the quantities that you might need. Remember to take on a few extra of each type, in case someone else on board forgets. Also check your instruments, cameras and computers for mercury button cells or specialized lithium cells that might go bad on a cruise.</td>
</tr>
<tr>
<td></td>
<td><strong>Battery C-cells</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Battery AA-cells</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Battery AAA-cells</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Battery 9-volt</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Battery, button cells</strong></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td><strong>Work Gloves, Pair (large)</strong></td>
<td>Work gloves get left all over the ship, so I always take extra pairs so that I can always find some when I need them.</td>
</tr>
<tr>
<td>6</td>
<td><strong>Bragbox towels</strong></td>
<td>We take an assortment of paper towels. The Bragbox towels are extra thick towels sturdy enough to clean wet instruments. The Kimwipes are thinner paper towels useful for cleaning spills around the lab.</td>
</tr>
<tr>
<td>10</td>
<td><strong>Kimwipes</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>Scotchkote 3M</td>
<td>Scotchkote is a thick, gooey, smelly, brown liquid that hardens into plastic coat when exposed to air. We use it to coat rubber splicing tape for underwater connectors. It’s quite messy so be careful when applying it (see towels above).</td>
</tr>
<tr>
<td>6</td>
<td>AC Power strip with surge protection</td>
<td>I always pay the extra money and get surge suppressors for each computer system on board a ship. Remember though that these do burn out when subjected to surges, so you should open up old units to check them out prior to each cruise. Burnt out parts within the units that we use (Isobar) are usually easily identified from their discoloration. If bad parts are discovered then toss the whole unit out and buy a new one. Also remember that these units can be burnt out by running them from square wave power inverters, as one of our engineers once discovered.</td>
</tr>
<tr>
<td>4</td>
<td>AC power strip</td>
<td>Standard power strips are handy for use with power tools and the like, but should not be used with computers or other sensitive electronic equipment.</td>
</tr>
<tr>
<td>2</td>
<td>AC Cube Tap</td>
<td>An electrician’s nightmare, these can be handy when working with power tools on deck using an extension cord back to the lab.</td>
</tr>
<tr>
<td>6</td>
<td>AC Male connectors</td>
<td>Combined with wire, these make good extension cords. We can also use them to fix broken equipment. If you are on a non-U.S. vessel, be sure to carry along some plugs suitable for that country’s electrical system.</td>
</tr>
<tr>
<td>6</td>
<td>AC Female connectors</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>AC extension cords 100 ft</td>
<td>AC outlets are never located where you want one, so take along an assortment of extension cords.</td>
</tr>
<tr>
<td>10</td>
<td>AC extension cords 10 ft</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>3 Conductor #14 AC cord, neoprene (ft)</td>
<td>If you need to make an even longer extension cord, or need to provide power to a distant instrument.</td>
</tr>
<tr>
<td>200</td>
<td>AC zip cord</td>
<td>Standard 16 or 18 gauge two-conductor zip (or lamp) cord can be handy for cheap wiring of a low-frequency signal or power from one place to another.</td>
</tr>
<tr>
<td>5</td>
<td>AC equipment cords</td>
<td>I always pack cords with the equipment, but one or two always seems to get lost.</td>
</tr>
<tr>
<td>1</td>
<td>500’ 4-conductor 18 gauge wire</td>
<td>Extra wire comes in handy for sending signals from one lab to the next or testing instruments on the fantail be connecting to computers in the lab.</td>
</tr>
<tr>
<td>1</td>
<td>500’ 6-conductor 20 gauge wire</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>Coax cable RG-214 (ft)</td>
<td>On board ship, we typically install video cameras and recording equipment, RF telemetry systems and other RF communications gear with remote antennas, and thin-wire Ethernet networks. All of these systems require coax cable. We typically just take a roll or two of each cable type, depending on our needs and the size of the ship, and make the cables to meet our needs on board. Heliax is a low-loss coax we use for RF modems that operate at 900 MHz.</td>
</tr>
<tr>
<td>1500</td>
<td>Coax cable RG-59 (ft)</td>
<td></td>
</tr>
<tr>
<td>1700</td>
<td>Coax cable RG-58 50 ohm (ft)</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>Coax cable RG-62 93 ohm (ft)</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1/4” Heliax</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>RG59 BNC Coax connectors</td>
<td>To make the cables on board, we use a variety of coaxial connectors. I prefer to use crimp on connectors as they are quite convenient. If you decide to use the same, just remember to bring along the proper trimming and crimping tools.</td>
</tr>
<tr>
<td>90</td>
<td>RG58 BNC Coax connectors</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Andrews 1/4” Heliax Connector</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Quantity</td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>5</td>
<td>Coax adaptor assortment, each</td>
<td>At last count there are approximately 27.46 zillion types of coax adaptors. We try to take along a handy assortment for BNC, N, UHF, SMA, and RCA connectors, along with a few more specialized types. The assortment contains barrels, T’s and type adaptors of both sexes. These little suckers are expensive so it pays to invest in some plastic trays to keep them sorted and together. In this way we just refill the trays prior to each cruise.</td>
</tr>
<tr>
<td>6</td>
<td>Epoxy 5 min Super glue</td>
<td>When things break, its nice to have glue.</td>
</tr>
<tr>
<td>8</td>
<td>RTV</td>
<td>RTV comes out of the tube like toothpaste, but turns into a rubber after a few hours of exposure to air or water. Its good for sealing instruments and junction boxes exposed to the elements. Be sure to use the more expensive non-corrosive variety when sealing electronic equipment.</td>
</tr>
<tr>
<td>3</td>
<td>DC-4 compound</td>
<td>DC-4 is a silicone grease that is applied to o-rings to insure a good seal.</td>
</tr>
<tr>
<td>2</td>
<td>Never-seez</td>
<td>Never-seez can be applied to nuts and bolts prior assembly to insure that the hardware will not bind when exposed to the elements. We regularly use this on buoy parts prior to deployment so that we can get the hardware apart again after recovery. This stuff stains so use it sparingly and be careful.</td>
</tr>
<tr>
<td>2</td>
<td>Krylon ultra flat black spray paint</td>
<td>A can or two of spray paint comes in handy for marking boxes, touching up buoy parts, and general marking of objects about the ship.</td>
</tr>
<tr>
<td>2</td>
<td>Krylon glossy white spray paint</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Swish</td>
<td>Swish is the tradename for an electrical contact cleaner that also displaces water. It is handy for cleaning connectors before mating. It is also one of the only known substances that Never-seez while dissolve in.</td>
</tr>
<tr>
<td>3</td>
<td>WD-40 Liquid Wrench</td>
<td>A penetrating oil is handy for those nuts and bolts that you forget to put Never-seez on. As an alternative I always try to use stainless hardware where I can, but some non-stainless hardware always seems to get mixed in.</td>
</tr>
<tr>
<td>4</td>
<td>Lacing cord</td>
<td>Lacing cord is handy for tying cable bundles and is just generally useful as a strong string. We typically use it for tying off meteorological balloons and attaching the radiosonde. While one roll of this would suffice, we normally take several because after two weeks at sea you can never find the one you are looking for.</td>
</tr>
<tr>
<td>3</td>
<td>Q-tips, pkg</td>
<td>These are great for cleaning things like your ears, the heads on tape drives and small parts.</td>
</tr>
<tr>
<td>10</td>
<td>Acid brushes</td>
<td>I use these for brushing on Scotchkote or for cleaning small parts.</td>
</tr>
<tr>
<td>60</td>
<td>Scotch pads (1 box)</td>
<td>These rough, yet non-abrasive, scouring pads are good for cleaning off sea crud from instruments and buoys after an extended deployment.</td>
</tr>
<tr>
<td>16</td>
<td>Pen marking Markal Sharpie</td>
<td>We use these indelible fine-tip marking pens for marking any surface, including plastics.</td>
</tr>
<tr>
<td>1</td>
<td>Alcohol, gallon</td>
<td>We use alcohol for cleaning connectors and instruments. We never use an entire gallon, but that is the size container that our stockroom has. A quart should be more than sufficient for purposes other than chemical analyses.</td>
</tr>
<tr>
<td>1</td>
<td>Wire markers pkg.</td>
<td>A package of printed wire marking labels is handy for those cases where tie wrap cable markers are inconvenient.</td>
</tr>
<tr>
<td>10</td>
<td>Plastic sheet 9x12</td>
<td>Generic clear plastic sheets are good for weatherproofing boxes or equipment left on deck or out in the open.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
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</tr>
<tr>
<td>4</td>
<td>Microduster refill</td>
<td>These small cans of compressed air are useful for blowing dust off of lenses and cleaning out connectors. As with any high pressure air, you should use eye protection during use.</td>
</tr>
<tr>
<td>1</td>
<td>Microduster nozzle</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>Zip-loc bags large 9x12</td>
<td>Zip-loc plastic bags are one of those other universally useful things to have on a cruise. I use them for storing small parts. I use them as a tool pouch. I bag everything when going out on a zodiac or other small boat to protect it from sea water. Sheets of paper can be encapsulated in the large bags for protection from the weather. Cable ends can be protected from the weather by placing them in a zip loc bag and wrapping with duct tape.</td>
</tr>
<tr>
<td>50</td>
<td>Zip-loc bags small 5x8</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>Zip-loc bags 8x10</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Floppy diskettes</td>
<td>Floppy disks are handy and cheap media for the exchange of data. We take along a few boxes on each cruise for just such exchange, even though we actually acquire data on larger capacity media such as hard disks, Bernoulli disks and Exabyte tape.</td>
</tr>
<tr>
<td>3.5&quot; high density, 10/pk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5&quot; double sided, 10/pk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5.25&quot; high density, 10/pk</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5.25&quot; 360K, 10/pkg</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3-1/4” Bernoulli disks, 90 MB, 3/pkg</td>
<td>We utilize Bernoulli disks for removable storage on our PCs and Macintosh computers. Syquest drives are a slightly less expensive alternative, but are not as reliable or as rugged, so I don’t use them in the field.</td>
</tr>
<tr>
<td>Nails assorted</td>
<td>Nails are handy for building things out of wood at sea AND we usually need them to nail the lids back onto the shipping boxes during the off-load. Since we usually begin packing on the way back to port, it is handy to bring the nails with you.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Crimp lugs for #22 wire (red)</td>
<td>Crimp lugs are useful for terminating electrical cables for connection to terminal strips.</td>
</tr>
<tr>
<td>20</td>
<td>Crimp lugs for #18 wire (blue)</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Crimp lugs for #16 wire (yellow)</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Lowel clips</td>
<td>Odds are that you have seen a lowel clip but don’t know it by name. These are plastic strips with ribbing on one side and a gripping attachment on one end that are used to secure a roll of cable. The clips are reusable and come with a handy eye on one end for hanging cables.</td>
</tr>
<tr>
<td>2</td>
<td>Solder</td>
<td>I usually pack at least two rolls, one fine for circuit board work and one thicker for attaching connectors and splicing cables.</td>
</tr>
<tr>
<td>1</td>
<td>Bus wire #22 roll</td>
<td>Some plain bare wire always comes in handy when trying to repair or rig a new circuit board.</td>
</tr>
<tr>
<td>6</td>
<td>Mousepads</td>
<td>Each computer these days needs a mousepad. I take along a few extras as replacements for those that get coffee spilled on them. They also make nice gifts to crew members with computers.</td>
</tr>
<tr>
<td>5</td>
<td>3 ring binders, 1&quot;</td>
<td>I like using three ring binders to organize the collection of daily on board data analysis products. I also include the typed log notes and any other papers that might even conceivably be useful in the post test analysis and interpretation of the data. I use the dividers to set up different sections in the book, typically organizing things chronologically. I used to take along just one 3 hole punch, but I could never find it when I needed it. Now I take along two. I still have difficulty finding either one of them, but at least I have doubled my chances of running across one when I need it.</td>
</tr>
<tr>
<td>7</td>
<td>3 ring dividers</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3 hole paper punch</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Erasers</td>
<td>See pencils, pens and mistakes elsewhere.</td>
</tr>
</tbody>
</table>
1 | Labels, box | A box of mailing labels is handy for labeling shipping boxes after packing during the offload. They are also handy for labeling the contents of storage boxes and drawers during the cruise. Just be sure that you can remove the labels easily before affixing them to anything permanently attached to the ship.

1 | Box laser paper | On at least two cruises that I have been on, I have seen scientists bring a laser printer but forget to bring any paper. While this is always worth a laugh, I don’t advise it.

2 | Laser printer toner cartridge | Don’t forget spare toner cartridges, just in case you run out or toner at sea.

1 | 3x3 post it notes, 12 per pack | The use of post it notes, those yellow square pads of paper with a weak adhesive on the back, on a cruise has its pros and cons. The pros are that its handy to have reminder notes stuck up around the lab. The con is that by the end of a typical cruise you may not be able to see any of your computer screens for the sea of post it notes.

I think there is some genetic failing in humans that make it nearly impossible to remove post it notes. This trait was likely selected for in caveman times. Archeologists have found small slabs of rock with directions to the hunt attached to the walls of caves with mastodon glue.

3 | Lab notebooks | I talked before about taking careful notes in a bound log book. Be sure to pack some.

1 | Notepads, 12 per pkg | If you are going to take pens and pencils, you should take some pads of paper to write on. The napkins in the galley will do in a pinch, but will definitely slow down your work. While I prefer to maintain my cruise log in a bound workbook, notepads are handy for quick calculations and can be used like a chalkboard when working with other scientists.

5 | Indelible marker (wide) | Great for marking boxes during the offload.

5 | Highlighter | Yellow highlighters are great for marking up important portions of logs or on board analysis results.

4 | Razor tip pens, 12 per box (1 box red, 3 black) | Be sure to get the kind whose ink doesn’t run when the page gets wet.

1 | Stapler | I often have the need for drawing a straight line or measuring distances. If navigation is important, you may also want to take your own dividers and other implements of the trade.

3 | Transparent tape, self-dispenser, 1/2" wide | 3M makes a clear tape which has a weaker adhesive than normal tape making it removable. This stuff is great for affixing schedules and notices to the lab walls. Regular tape is best for affixing plots and tables into your cruise log.

2 | Architects ruler | The use of scissors will be left as an exercise to the reader.

12 | 0.5 mm Pentel Pencil | If you are like me and never make mistakes, take pens. Those among us that are fallible, should pack some pencils. (Note erasers, elsewhere.)

3 | 0.5 mm 2B lead | 0.5 mm 2H lead

2 | Scissors | I like my paperwork neat and organized. It never is, but that is the way I like it. I always take folders along on the off chance that I might actually get organized one of these days. And when that day comes, I want to be prepared.

1 | Manilla Folders, box |
We use Exabyte 8 mm digital tape drives for recording raw data and for system backups in the field. It is also a handy media for the exchange of large amounts of data, especially because a $7 tape can hold 5 gigabytes of data. While we use these systems on IBMs, Macs and UNIX boxes, they are almost universally software compatible on UNIX systems when using tar backup format.

These tapes are also useful as 8 mm video tapes, although the video grade tapes are less expensive than data grade. (Don’t try to use video tapes in your data recorders, several years ago it used to work, but they changed the formulation of the tape so this no longer works.)

<table>
<thead>
<tr>
<th>20</th>
<th>8mm Exabyte/ Sony video tape</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>We use Exabyte 8 mm digital tape drives for recording raw data and for system backups in the field. It is also a handy media for the exchange of large amounts of data, especially because a $7 tape can hold 5 gigabytes of data. While we use these systems on IBMs, Macs and UNIX boxes, they are almost universally software compatible on UNIX systems when using tar backup format.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9</th>
<th>25-pin D connector, solder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>male</td>
</tr>
<tr>
<td>9</td>
<td>female</td>
</tr>
<tr>
<td>18</td>
<td>25 pin connector shell</td>
</tr>
<tr>
<td></td>
<td>I always take along an assortment of RS232 connectors for creating cables in the field. These are handy to replace failed cables as well as creating new cables to link your computers with those of other scientists.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>9</th>
<th>9-pin D connector, solder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>male</td>
</tr>
<tr>
<td>9</td>
<td>female</td>
</tr>
<tr>
<td>18</td>
<td>9 pin connector shell</td>
</tr>
<tr>
<td></td>
<td>While as a Mac person, I usually stick to 25 pin connectors, some obscure computers, known as IBM PC compatibles, use 9-pin connectors. Although I’m sure you’ll never run across such primitive machines in your work, it is still good to be prepared.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>RS232 gender changer, male</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>RS232 gender changer, female</td>
</tr>
<tr>
<td>2</td>
<td>RS232 null modem</td>
</tr>
<tr>
<td></td>
<td>RS232 connectors come in several flavors. A corollary of the Law of RS232 Connector Transmutation, first discovered by an obscure computer scientist in the early 1950’s, states that whatever connector you have at the end of a cable will not match the device you want to plug into. Thus the need for an assortment of adaptors.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3</th>
<th>Mini DIN-8 to DB25 cable, Mac</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Modem cable for connecting Apple Macintosh computers to modems, serial devices or IBM-compatible computers. These are useful even if you don’t have a Mac, because it is likely that someone else on board will. I take several along because I use Macs instead of IBMs.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2</th>
<th>Loctite (blue)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>6</th>
<th>Solder wick 3/32</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This copper braid is used with a soldering iron for removing solder from solder pad on a circuit board. Removing an IC from a board without damaging the board is almost impossible without this.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>Desoldering supplies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hook up wire assortment</td>
</tr>
<tr>
<td>15</td>
<td>DB-25S crimped pin</td>
</tr>
<tr>
<td>15</td>
<td>DB-25P crimped pin</td>
</tr>
<tr>
<td>15</td>
<td>DB-9S crimped pin</td>
</tr>
<tr>
<td>15</td>
<td>DB-9P crimped pin</td>
</tr>
</tbody>
</table>
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Appendix D. Knots

**Overhand Knot**

Use: Tying two ends together, to keep from slipping through a hole, safety in tying another knot.

**Figure Eight Knot**

Use: To keep the end of a rope from coming through a strop.

**Square Knot**

Use: For package tying, or wherever a simple knot is needed to join two ropes of the same size. Jibted uses have only 50% the strength of new line.

**Not This - a Granny Knot**

**Carrick Bend**

**Sheepshank**

Use: To shorten a rope.

**Sheet Bend**

Use: To join two light lines or two light unequal sizes. Jibted uses have only 60% the strength of new line.

**Bowline**

**Round Turn and Two Half Hitches**

Use: To secure a line or rope to a point, while it is necessary to pass the rope around a pole or ring.
TIMBER HITCH
1. Place around object.
2. Start to twist back on itself.
3. Take about three turns
4. Finish with one or two half hitches
Use: In making low cylinder objects

CLOVE HITCH
Use: To fasten a rope around an object. It is used at the end of a rope to keep knot small around the bending part.

PACKAGE KNOT
Use: To keep rope from slipping when spliced.

BOWLINE ON A BIGHT
1. Fix B into A
2. Bring bag A down and put over bag B
3. Tie up by passing end of B through
Use: In making low cylinder objects.

CATSPAW
Use: To make a ring or other from a knot in a rope.

FISHERMAN'S KNOT
Use: In making low cylinder objects.
Dedication

This book is dedicated to my late father, George Chapman. He taught me the values of hard work, the benefits of treating people with respect, and the advantages of common sense. What I am today, I owe to him.